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TEA AND SOIL ACIDITY III.

Pot Culture Experiments,

By

C. H. GADD.

The necessity for a suitable degree of acidity of a medium surrounding the roots of a tea plant has been demonstrated in experiments with water culture solutions (T. Q. Vol. 1, pp. 2-6, 31-35). As the plants were grown under unnatural conditions, *i.e.*, in water culture solutions, no great importance can be attached to any specific pH value determined to be an optimum from those experiments. The experiments demonstrated that the growth of tea seedlings can be controlled to a large extent by alterations in the reaction of the medium surrounding the roots, and that pathological symptoms can be induced with solutions approximating neutrality, and corrected when the acidity of the solution is increased.

It was necessary, therefore, to determine how far such conclusions hold good when seedlings are grown under natural conditions, and what soil reactions most favour the growth of tea.

In the following experiments, the black Nuwara Eliya soil was used. Sufficient soil for 6 twelve-inch pots was thoroughly mixed before the pots were filled. To the soil of each pot was added $\frac{1}{5}$ oz. (equivalent to approximately 1 ton per acre) of a suitable fertiliser and a predetermined quantity of lime or sulphur. The fertiliser, which was kindly supplied by the Colombo Commercial Co. consisted of:—

Crushed fish	2 parts by weight
Muriate of potash	$\frac{1}{3}$,, ,, ,,
Nitrate of soda	$\frac{1}{2}$,, ,, ,,
Ephosphosphate	3 ,, ,, ,,

The pots were prepared on December 20th 1926. As varying amounts of lime and sulphur were mixed with the soil to alter its reaction, the sulphur to make it more acid and the lime to render it less acid, the pH value of each prepared soil was determined a fortnight later. These determinations were made colorimetrically. After the termination of the experiment, the pH values were again ascertained; this time potentiometrically. The writer is indebted to Mr. T. Eden for the final determinations. He used the quinhydrone cell with gold electrodes.

The amount of sulphur or lime added to each pot and the ascertained pH values are given in Table 1, from which may be seen that approximately 10 tons of lime per acre were required to bring the original soil to neutrality.

TABLE 1.

Pot No.	Treatment applied Sulphur ozs.	Lime. ozs.	Equivalent Tons per acre.	pH Values Initial	Final
1	1	—	2	4·8	4·07
2	—	—	—	5·8	5·34
3	—	2½	5	6·7	6·53
4	—	5	10	7·1	7·23
5	—	7½	15	7·4	7·66
6	—	10	20	7·6	7·77

On January 18th 1927, three healthy tea seedlings were planted in each pot. Before transplanting, the cotyledons (seed) were removed in order that any food reserves remaining in them would not affect the experiment. The plants were sufficiently well grown to be self supporting. The pots were then placed in the laboratory verandah under similar lighting and other conditions. It soon became evident that the slightly alkaline soils of pots 5 and 6 were unsuitable for the tea seedlings. Although the plants produced new leaves, the stems did not elongate normally, nor had the leaves a healthy colour. The leaves which expanded during the experimental period were yellowish; two plants in pot 6 produced almost white leaves.

By September, it became apparent that the plants in pot 6 were dying; the sickly leaves had fallen off, though the original green leaves, developed before the experiment started, remained normal. On September 8th, these plants were removed from the soil and weighed. Two were removed to a more acid soil, while the least unhealthy plant was replaced in the soil under experiment. The two transplanted seedlings failed to recover; the other was still alive at the end of the experiment on March 14th 1928, but it had made no new growth. In fact its final weight was less than that ascertained in September.

One plant in pot 5 died in October. This seedling produced 3 small yellow leaves during the course of the experiment.

TABLE 2.

Pot No.	No. of plants in pot.	Fresh Weights Initial gms.	Final gms.	Increase in Fresh weight. gms.	Increase as a percentage of initial weight. Per cent.	Final dry weight. gms.
1	3	6·73	44·54	37 81	562	11·57
2	3	4·76	53·91	49·15	1032	14·11
3	3	5·96	65·85	59·89	1005	15·68
4	3	4·78	31·22	26·44	553	7·65
5	2	3 94	6·65	2·71	69	—
6	3	5·26	6·27	1·01	19	—

In Table 2 are given the initial and final fresh weights of the seedlings in each pot. The final weight of the plants from pot 6 is

that determined in September before any of the plants died. As one plant died in pot 5, the initial and final weight of the remaining two only are recorded.

The increase in weight gives a fair representation of the growth of the plants as may be seen from Plate 1, in which are reproduced photographs taken when the experiment terminated. It may be seen from Table 2 that the seedlings in pot 3 made the greatest increase in weight, whereas the plants of pot 2 give the best result if the criterion is the increase in weight expressed as a percentage of the initial fresh weight. The latter method of comparison is the better as it is to be expected that, other things being equal, plants with the greatest initial weight will make the greatest nett increase in weight. We need not here attempt to determine which of these results is the better; it is sufficient to note that the results obtained from pots 2 and 3, which received no lime and 5 tons per acre respectively, are markedly better than those from other pots.

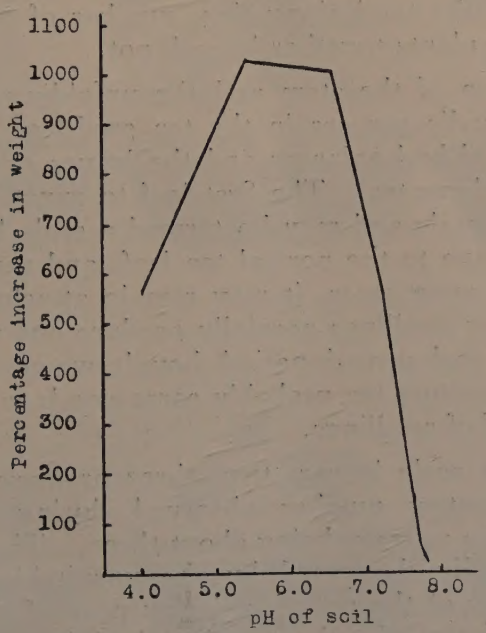


Fig. I Graphs showing the influence of soil reaction on the growth of tea seedlings.

In Fig. 1 the percentage increases in fresh weight are graphed against the pH value of the soil in which the plants were grown. This diagram shows that the maximum growth occurs in soil having a pH value between 5·3 and 6·5. As the pH value increases above 6·5, *i.e.*, as the soil becomes less acid or more alkaline, the growth of tea seedlings diminishes markedly, as is shown by the rapid fall

of the curve on that side. A small alteration in the pH value of the soil above 6·5, therefore, has a decided detrimental effect on tea seedlings growing in it.

There is a similar but less steep fall on the acid side of the curve. As the pH value of the soil falls below 5·3, the seedlings show a smaller percentage increase in weight. This decrease, however, is not so marked as that at the other end of the scale. Thus, an alteration of the soil reaction from pH 5·3 to 4·0 has much less effect than an equal change from pH 6·5 to 7·8. At the last named value, the reaction is so unsuitable for tea that the plants develop pathological symptoms and die.

Growth records were made monthly throughout the experiment. Measurements were made of the elongation of the stems, and the newly developed foliage leaves were counted. A summary of these observations is given in Table 3. The figures given there are not averages, but are the total elongation, number of new leaves, etc. made by the three plants together in each pot.

The elongation of the stem and the unfolding of new foliage leaves is a spasmodic process in the tea seedling. When growth begins, the terminal bud enlarges and the leaves expand in succession as the stem elongates. The first leaf to expand is very small, little more than a scale and may be termed a scale leaf. It has no resemblance in shape to the normal tea leaf, and usually it falls off early, though, in some cases, it may remain attached to the stem. Vigorously growing seedlings normally produce one scale leaf at the commencement of each growth period though two are not uncommon. The 'fish' leaf in mature tea probably corresponds with what is here termed a scale leaf of seedlings.

Following the scale leaves, two, three or more foliage leaves expand. The greatest number observed during one period of growth was ten; the average being about three. The average, however, is undoubtedly depressed by the unsuitable soil conditions established in some of the pots for the purpose of this experiment. After a period of growth, the terminal bud becomes inactive or dormant, and may remain so for several months. Thus, periods of growth alternate with periods of dormancy. When the terminal bud remains inactive after the last expanded leaf is mature, the condition closely resembles what is termed 'bhanji' in mature bushes. An investigation into the causes which underlie and determine the growth periods of seedlings would probably throw some light on the problem of 'bhanji' in mature tea.

PLATE I.

TEA SEEDLINGS GROWING IN SOILS OF VARIOUS REACTIONS.

TABLE 3.

Pot No.	Stem Growth.	No. of new leaves.	No. of growth periods.	No. of Nodes.	Mean internodal length.
	cms.				cms.
1	31·8	19	9	30	1·06
2	56·7	32	11	49	1·16
3	100·4	47	12	60	1·67
4	21·0	18	9	34	0·62
5	3·5	11	5	—	0·32
6	2·3	10	4	—	0·23

It may be seen from Table 3 that the growth is progressively greater in pots 1, 2 and 3. The greatest growth was made by the seedlings in pot 3, as may be seen from the photographs. These plants also produced the largest number of new leaves. In pots 4, 5 and 6 the growth is progressively less.

There appears to be a marked correlation between the increase in length of the stems and the number of new leaves produced. Also, the plants with the greatest number of leaves have them spaced at greater intervals along the stems, *i.e.*, the mean internodal length is greater. When calculating the mean internodal length, the scale leaves as well as the foliage leaves were counted, except in pots 5 and 6, foliage leaves only were included. Had the scale leaves been included in the calculation for the latter pots, the mean internodal length would have been correspondingly smaller.

The shortening of the internodes and the yellowing of the leaves exhibited in pots 4, 5 and 6 are of interest, as such must be regarded as pathological symptoms. In certain respects, the symptoms resemble those of the disease known as Witches Broom of older tea. The yellowing of the leaf is not a constant character of the Witches Broom disease, but the presence of short shoots on which the leaf scars are closely crowded is a very constant character of the disease. The writer does not consider that these experiments constitute a proof that Witches Broom disease of tea is caused by unsuitable soil acidity; but the fact that unsuitable hydrogen-ion concentrations (high pH values) of the soil have a tendency to cause the leaves to become crowded on the stem and yellow in colour, supports the tentative couclusion, drawn from field observations, that the Witches Broom disease of tea is caused by adverse soil characters, possibly associated with soil acidity.

It is sometimes said that tea will not stand lime. Such a broad generalisation is somewhat unreliable, because whatever action lime may have is effected through the medium of the soil. Any effect the lime may have on the tea will depend upon the result of the interaction of the lime with the soil. All soils will not react alike. In the present case the addition of lime at the rate of 5 tons per acre had no detrimental effect on the tea seedlings; on the contrary it appears to have had a beneficial effect, if judged by the elongation of the stem and the production of new leaves. But, if judged by

increase in weight, the beneficial effect is not great. There is, however, no evidence of any detrimental effect.

It should be noted, however, that the original soil was somewhat acid (pH, 5·3) and that 5 tons of lime per acre reduced the acidity to a pH value of 6·5. If the original soil had a pH value of 6·5, a 5 ton application of lime would have increased the pH value to 7·2 and the effect of this on the tea seedlings would have been markedly detrimental, as is shown by pot 4. Not only must the original soil reaction be considered, but the buffer action of the soil also has to be taken into account. The first 5 tons of lime caused a change in soil reaction of 1·2 units in the pH scale. A further 5 tons altered the value by 0·7 units only. As the soil reached neutrality it resisted further alteration; such phenomena are known as buffer actions. All soils have not equal buffer actions, so 1 ton of lime may have a much greater effect on the reaction of one soil than it has on another. It is, therefore, advisable to view the problem of the value of lime in tea cultivation more from its effect on soil reaction as measured on the pH scale than from the actual amount of lime used.

Under the conditions of this experiment, the maximum growth occurs when tea seedlings are grown in soils with pH values lying between 5·3 and 6·5. As the value rises above 6·5, the soil becomes detrimental to tea seedlings, and pronounced pathological symptoms become evident before the soil reaction reaches a value of pH 6·7. The detrimental effect of a high degree of soil acidity (*i.e.*, a low pH value) is not so marked as that which results from an alkaline reaction. In other words, for tea cultivation, a soil which is too acid is better than one which is insufficiently acid. Haphazard applications of lime, particularly if the tea appears weak, are more likely to do harm than good. This may afford reasons for the conflicting views regarding the value of lime in tea cultivation and for the generalisation that tea will not tolerate lime.

SUMMARY.

Tea seedlings were grown in soils of different reactions. Changes in soil acidity were brought about by additions of sulphur and lime in varying quantities.

The addition of lime at the rate of 5 tons per acre had a marked beneficial effect on the aerial growth of the seedlings. When increase in weight of the seedlings is used as a criterion, the benefit derived from the lime is not so prominent.

The value of lime in tea cultivation must be considered more from its effect on the soil reaction as measured on the pH scale than from the amount applied, as different soils react to lime in differing degrees for equal additions of lime.

The optimum pH value of soil for tea lies between 5·3 and 6·5. Higher values may have very detrimental effects and lead to the development of pathological symptoms. Lower values are not so harmful.

CO-OPERATIVE LIMING TRIALS.

By

T. EDEN, M.Sc., A.I.C.

The question of the effect of lime on the growth and yield of tea is one which continues to arouse interest and discussion in Ceylon. Unfortunately, there is a lack of accurate data from which conclusions can be drawn.

The most quoted source of information is that provided by the co-operative manuring and liming trials, which were carried out on a number of estates under the supervision of the Department of Agriculture, at various times between 1904 and 1911. Since these trials represent practically the whole data which is definitely to the point, and since no published examination of the experimental results appears to have been made, it seemed advisable to the writer that these data should be examined as a preliminary to further work on this subject. The original records were made available by the kindness of the Director of Agriculture to whom our thanks are due.

As far as the question of liming is concerned, the co-operative trials included three plots of interest. These received the following treatments:—

1. 1000 lbs. of lime per annum.
2. 500 lbs. of lime per annum.
3. Untreated.

The lime was applied as a mixture of equal parts of burned and finely ground coral lime. The analyses of the Government Agricultural Chemist show that 1000 lbs. of such a mixture would contain only 515 lbs. of calcium oxide or 580 lbs. of slaked lime. For the purposes of this paper, attention has been confined to the comparison between the controls and the plots to which was applied the larger quality of lime only.

The experiments consisted of single plots only of each treatment, and since the records give no indication of plot size, the actual yields per plot have been made the basis of all calculations. On examination of the records it was discovered that they were incomplete. As it would be unsatisfactory to compare less than a complete pruning cycle, attention is confined to the four out of seven cases where complete data were available.

The fact that only single plots were used makes impossible a direct estimate of the errors involved. Moreover, single plots provide no check upon the possibility that one of the two plots under comparison was initially of a higher fertility than the other. If this were the case, any difference between the yields of the two treatments is likely to be due to initial fertility and not to subsequent treatment.

There is no previous history of the plots available to throw light on this point.

Under these circumstances a somewhat round about method had to be used to compare the behaviour of the limed and unlimed plots. The assumption underlying this method is that if liming is beneficial, the limed plot should, in course of time, show signs of gaining on the unlimed, and, if adverse, signs of losing.* This gain or loss should occur no matter what were the initial yields of the two comparable plots before treatment. For example, if liming is harmful, even though the limed plot in the first place gave a higher yield than the control, we might expect that this original advantage which the limed plot had, would gradually become less pronounced. If liming is beneficial, the discrepancy between the yields of the two plots would tend to increase.

Before testing the data in this manner, the limed plot monthly yields were expressed as a percentage of the control. In this way results more comparable with one another were obtained than if direct differences were taken. Direct differences are affected to a much greater extent by the periodic variation of total crop. These percentage values were then plotted in a graph against the monthly time intervals into which the pruning cycles were subdivided. One such graphical representation of the data is given for the Haputale experiment in Figure I.

The problem consists of deciding whether the general trend of these values is increasing or decreasing. The variation in yield of the limed plot, expressed as a percentage of control, is here shown to be very great, and from the result of casual inspection it would be difficult to say whether or not the trend of the values was upwards or downwards. When, however, mathematical methods are employed, the general trend of the results can be expressed in the form of a regression line A B. Such a line is shown in the diagram and represents the straight line which most closely fits the twenty seven points. This regression line shows that the trend of the results is upwards, *i.e.* that the limed plot is steadly gaining on the control. The position on the line marked by the cross is the average of all the values, viz: 111·6. The dotted line gives the level of the control. Hence, on the whole, the limed plot has been superior to the control. The regression line shows that some, at least, of that superiority is due to initial plot fertility.

The actual rate of gain of the limed plot on the control is shown by the slope of the line, and is numerically equal to BC/CA which is called the regression coefficient. Had there been no gain, the regression line would have been parallel to the horizontal or time axis of the graph, *i.e.*, to the control line. Before the gain can be

* Fisher, R. A. 1925 Statistical methods for Research workers.

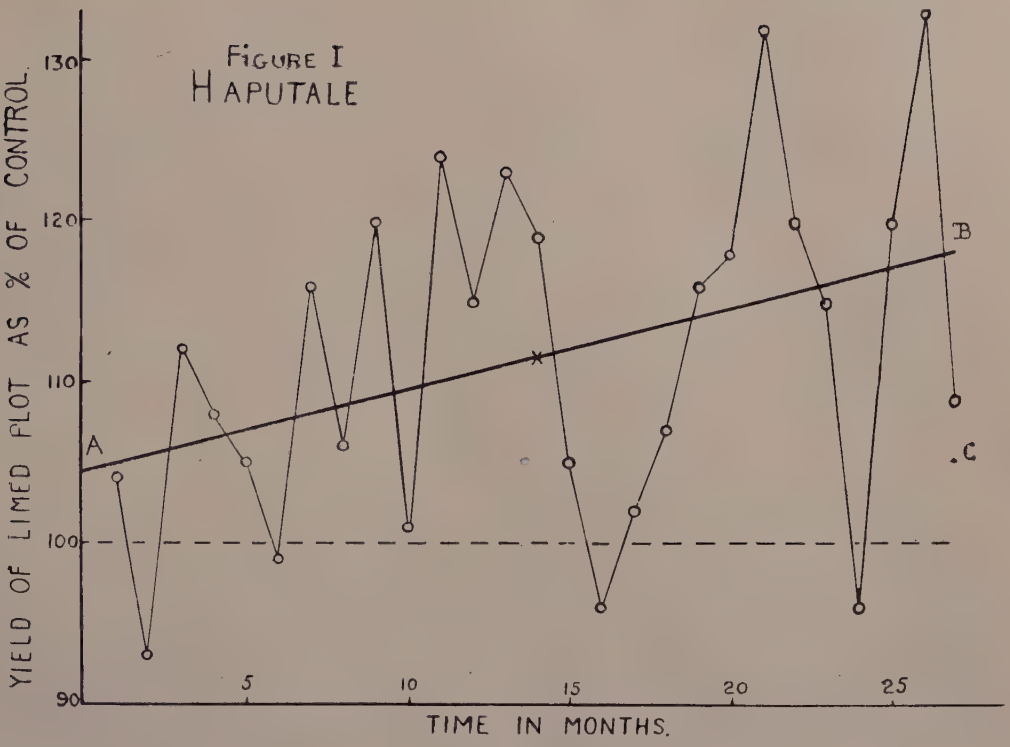
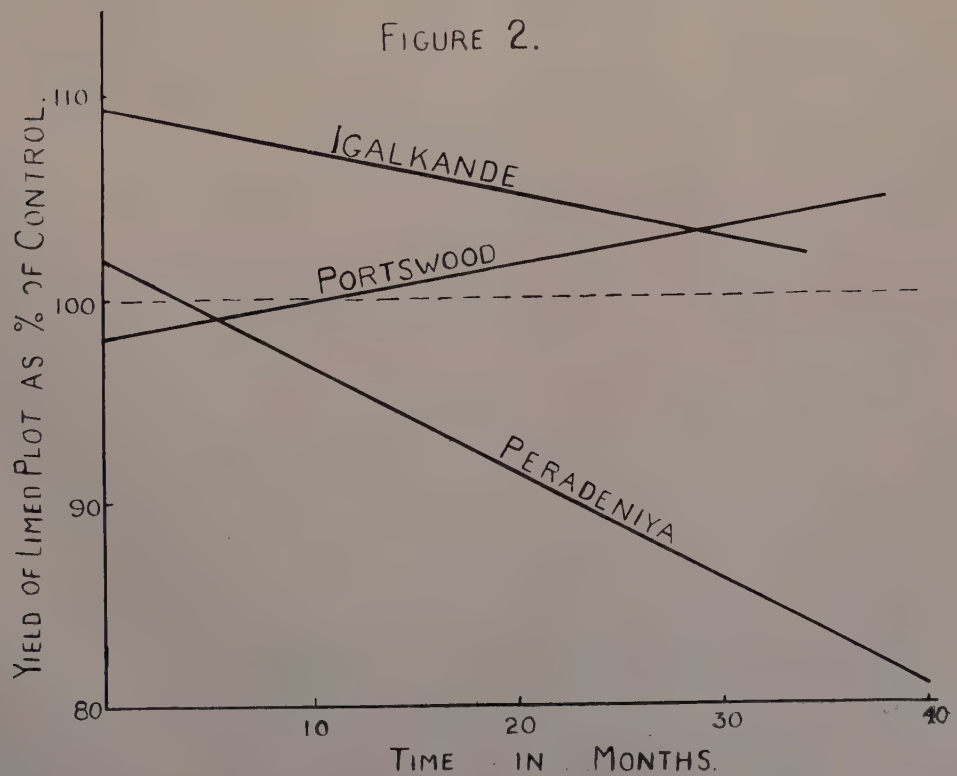


FIGURE 2.



CO-OPERATIVE LIMING TRIAL REGRESSIONS.

judged significant, however, the error of the estimation of the regression coefficient must be calculated. This may be so great as to invalidate the significance of the coefficient, in which case the contention that the limed plot shows a significant gain on the control would have to be regarded as unproven. The results of this further examination together with the other relevant data are given for the Haputale plots in the first line of Table I.

TABLE I.

Estate.	Regression Coeff. (limed as % of control)	*t* calculated	*t* significant	Mean yie'd of limed as % of control.
Haputale	+ ·51	2 .06	2 ·06	111 ·6
Peradeniya	— ·53	2 .03	2 ·03	91 ·1
Portswood	+ ·18	.30	2 .03	101 ·6
Igalkande	— ·21	·70	2 ·04	105 ·6

The test of the significance of the value of the regression coefficient is what is known as the *t* test. The second and third columns of figures give respectively the values of *t* calculated from the actual data, and the values of *t* which must be exceeded or equalled if the regression coefficient values are to be judged significant.

In the case of the *Haputale* figures, the test shows that the regression coefficient is just significant. Hence, in this case, liming appears to have been slightly beneficial.

The regression lines for the other three sets of data are given in Figure 2. For the sake of simplicity, the actual yield points from which they were calculated are omitted. In conjunction with the data in Table I, the findings are as follows:—

Peradeniya, judged by mean yield, shows the lime plot to be inferior to the control. The regression coefficient is, comparatively speaking, high and is negative. The fact of being negative indicates that the yield of the lime plot is falling off compared with the control. (Cf. graph in Fig. 2. The Peradeniya line falls from left to right and is unlike the Haputale line representing a positive coefficient). Starting almost level with the control at a value of 102 it finally drops to 81. The calculated *t* value from these data is equal to that required for significance so that in this case the falling off is real, and the lime appears to be harmful.

The *Portswood* figures, with a mean of 101·6, show a small positive coefficient corresponding to a slight gain on the part of the limed plot. On testing the significance, the value of *t* obtained falls far below that required, and accordingly the gain cannot be regarded as real. In this case the effect of lime is unproved.

Igalkande has a mean value for the limed plot of 105·6, but despite this apparent superiority of the limed plot, the negative regression coefficient shows that the initial advantage is being steadily lost though it is never completely cancelled.

This argues a harmful effect of lime. Like Portswood, however, the error associated with this value of the coefficient is so high as to vitiate all conclusions since t is only ·70, whereas a value of 2·04 is required to prove the case.

To sum up, the co-operative liming trials have been examined statistically to determine whether, in the examples given, 1000 lbs. of lime per annum have heen harmful or beneficial. Of the four experiments so tested, one shows lime to be slightly and definitely beneficial, and one shows it to be slightly and definitely harmful. The other two centres give indefinite results since the errors are so high as to vitiate any conclusions.

It is evident, therefore, that the question will have to be investigated further in the field by means of experiments of much greater accuracy. Also, consideration will have to be given to the prevailing soil conditions, which may affect the problem of whether lime in these and other quantities is harmful or beneficial.

PRUNING IN RELATION TO WOOD ROT OF TEA.

By

C. H. GADD.

Rotten wood of any kind is a diseased condition; and this disease is the work of living organisms. The rotten wood within the cavities, known as Branch Cankers, in the stems of tea bushes is the result of the activities of various fungi which use woody tissues as a source of food supply, and by so doing, alter the chemical composition and physical characters of the wood. In this respect, wood rot of tea is similar to dry rot of sawn timber, though the specific fungi which bring about these conditions are not necessarily the same.

The bark, which forms the outer covering of a tea bush, constitutes a complete protection against the invasion of wood rotting fungi, which gain admittance only through wounds exposing the woody axis. As the tea bush has to be pruned at frequent intervals for convenience in harvesting the crop, there is good reason to suppose, and much evidence to justify the supposition, that most of the wood rot prevalent in tea at the present time is the direct consequence of pruning. More harm can be done in one round of pruning than by any other routine operation in the cultivation of the tea bush.

That ideas on pruning are largely notional will be realised on studying the numerous methods which have been in vogue at different times on fruit trees. The same is equally true of tea pruning, but here there are decided limitations, one of which is the skill of the cooly. The cooly has to be given definite simple instructions which will apply equally to all the bushes in this task. He must cut back the bushes to a given height, or he must prune two inches above the last cuts and so on. There are, however, a number of basic principles underlying all systems of pruning, the observance of which constitutes good pruning. These principles will briefly be considered in so far as they bear on the problem of wood rot.

As the fungi which cause wood rot enter the bush via the pruning cuts, it may appear immaterial how the bush is pruned, because wounding cannot be avoided. That would probably be true if wounds never healed. But it is well known that some wounds heal readily and that when healed, the wounds are completely protected against the invasion of wood rotting organisms. It is not generally realised that the position of a wound is, in many cases, the deciding factor whether that wound will heal or not.

To explain the process of healing in woody plants, it is necessary to describe briefly the structure of a stem. On the outside of the woody cylinder and beneath the cortex or bark is a thin tissue known as the cambium. Broadly speaking, the cambium is the source of all growth in thickness; it produces wood on its inside and soft cortex on its outside. As the outer bark is ruptured by the expansion of the stem, parts of the inner cortex gives rise to a corky protective layer. A surface wound, which merely abrades the cortex, is readily healed by the formation of cork cells, but a wound which exposes the wood can only be healed by growth from the cambium.

The wood which is formed on the inside of the cambium soon becomes lifeless and has no power to grow or form new tissues. When a branch is cut off, the wound is approximately circular. The central cylinder of wood is exposed, but this cannot heal in the way flesh wounds heal. A mass of tissue, known as callus, grows out from the cambium and forms a ring around the exposed wood. This ring of callus grows over the wood, inwards from all sides, until the whole wound is completely covered, but it does not fuse nor form a vital connection with the wood.

The callus which covers the wound, then, is the resulting growth from the cambium for which a food supply is required. The food supply is manufactured in the leaves and is transported in the cortex (or inner bark). Only when wounds are located along the lines of transfer of this food supply or at places where active growth is taking place, can healing tissues develop.

If wounds are to heal they must be made in suitable places. Two examples only need be considered (1) a branch is to be completely removed, and (2) a branch is to be cut back, but not entirely removed.

When a branch has to be removed, it should be cut off as close as possible to the parent branch. The wound is then in the line along which food materials are transported along the parent branch. If a stub is left, the wound is not along a food supply line, but is separated from it by the length of the stub. That is the reason why stubs do not heal; the longer the stub the less likely is the wound to heal. The importance of cutting off a limb flush with the parent branch will be realised on examining wayside trees. Where the pruning is flush, healing progresses readily; but where stubs have been left, there is a mass of rotting wood but no healing.

On some estates, stubs are left purposely. It is sometimes suggested that although the stub dies back and rots, the healing callus will form below it and ultimately cut it off. Such an idea should be dismissed at once as a mechanical impossibility.

When a branch has to be cut back or shortened, the cut should be made with a gentle slope just above a bud (eye), the bud being situated near the upper end of the cut. The mere cutting of the branch, as a rule, stimulates the uppermost remaining bud into growth, and a food supply is directed to that point. If the wound is immediately above the bud, it is at a place where active growth will take place and will receive a food supply necessary for the healing process. If however, the bud does not grow, the wound will not heal. When a length of stem is left between the cut and the nearest bud, that stem usually dies back; and the wound does not heal as a rule.

In general, the healing of a wound takes place most quickly, other things being equal, when a strong bud or branch stands close to the wound, provided always that this bud is not injured by the drying out of the stub. A wound caused by the amputation of a branch must, in order to heal properly, be made perfectly even with the parent stem. In these two statements lie the main principles which control the position of good pruning cuts.

The season of pruning is a subject of many opinions. As healing is a process of growth, pruning should not be done at a time when the cambium is inactive. As tea is an evergreen shrub, there is no time of the year during which its cambium can be said to be definitely inactive. Theoretically, so far as the healing of wounds is concerned, the best time to prune is just before the bushes are expected to make good growth; that is not in the middle of a long drought. Practically, the best time is when labour is available and when most care can be given to the job. In all probability, more depends on the

position of the wound and the length of the stub than on the time of pruning.

In the pruning of trained trees, European gardeners often take off the shoots in winter when time is to spare, leaving the stubs two or three inches longer than desired; in spring, an assistant, who may not have had sufficient experience to block out the pruning goes over the trees and cuts back the stubs to fresh buds. A similar practice is not unknown on some tea estates, where it is known as second pruning. This idea is worth consideration when pruning has to be carried out during periods of drought or at times known from experience to be unfavourable for tea.

As the entrance of living organisms from the atmosphere constitutes the great danger to wood wounds, it follows that a wound which is smooth and solid is safer than one which is haggled and splintered. Surfaces which will retain moisture, and contain crevices in which the germs can lodge, favour the entrance of the wood rotting organisms. It is conceivable also that the progress of the cal us is also obstructed by projecting splinters. Ragged wounds seldom heal without becoming seriously diseased.

It follows that the pruning coolies should have suitable tools for the work in hand. If thick branches have to be cut, something more than a pruning knife may be necessary. Many superintendents will not allow a saw on the estate. There is good reason behind such a rule in so far that unnecessary large wounds must be avoided. But tea wood is not easy to cut, and when a coolie has to put his whole weight on his knife or if he uses his knife as a hatchet when master is not looking, he usually ends by splitting the branch, though he may trim the wound in an attempt to hide the damage. As much depends upon the condition of the bushes and the size of the branches to be cut, the abolition of the saw does not necessarily signify an improvement in the pruning methods.

The healing of wounds in tea is normally a slow process and much time, depending upon the size of the wound and other conditions, elapses between the making and complete healing of the wound. During this time the wound is liable to infection, as complete protection is not afforded until the wound is completely healed. A certain misconception has been prevalent of late years regarding this point, namely, that the wound is completely protected from the time healing begins. The wood rotting fungi will attack the exposed wood whether healing has begun or not. Moreover, even after the wound is completely covered by callus, the mycelium of the fungus will continue its growth in the wood, and cause the stem to become hollow if infection occurs before the wound is covered.

If these facts are admitted, it follows that wounds should be protected artificially until completely healed over. As there is a

strong difference of opinion regarding the necessity for wound covers for tea in Ceylon, some explanation of the scientific data on which these conflicting views are founded may be necessary.

It is well known and proved beyond all doubt, that certain trees form a substance known as wound gum in the tissues below wounds, and it is suggested that tea behaves similarly. If tea forms a wound gum below pruning cuts, it should easily be demonstrable to a botanist and the matter placed beyond question. In my experience, and I have examined a large number of pruned stems of different ages, I have seen nothing resembling a wound gum in tea. My results have been entirely negative.

Moreover, it has been shown that when wound gum is formed, it is derived directly from starch. Tea does not store starch in the stems as a rule, but in the roots. Starch may be present in the stems of tea seed bearers, but in tea in plucking it is unusual. The absence of starch from tea stems affords a simple explanation of the absence of wound gum below pruning cuts.

The advocates of the wound gum theory in tea have overlooked the fact that existence of the gum would not constitute a proof that it is a preventive against the entrance of fungi. The use of artificial wound covers is advocated by scientists who have investigated the subject of wound gum, for trees in which they have demonstrated the existence of a wound gum. They do not regard it is an efficient protection against wood destroying fungi. If tea forms wound gum, its inefficiency as a wood rot preventive can be demonstrated on any tea bush though its existence cannot.

The denial of the formation of wound gum in tea does not decry the importance of callus formation or healing. The two processes are entirely different and unconnected. The one is an outgrowth from the cambium; the other results from a transformation of starch.

A dressing or application to a wound cannot directly hasten the healing process though by preventing the decay of the parts it may be the means of saving the branch. Dressings must be regarded as preventive, not curative; they are on par with the antiseptics used by a surgeon, in that they prevent contamination of the wound and thereby allow nature to heal it.

The proper dressings for wounds, or, whether any dressing whatever is advantageous, is another controverted problem. The many and various experiments conducted on all sorts of trees are not conclusive, nor even harmonious. The reasons for this need not be discussed here, though one comment may be offered. The criterion of a wound dressing experiment should be the protection afforded to the wood against decay, and not the rate of healing. The practice of applying wound dressings rests on sound rational principles; and it may be accepted almost as an axiom that the slower the healing and the larger the wound, the more necessary is a protective dressing.

A dressing for wood wounds must possess two positive qualities —it must afford protection against the weathering of the wood, and against invasion by fungi. In other words, it must be a protective compound and an antiseptic. At the same time, it must have no injurious effect on the cambium and cortex. To afford efficient protection, the dressing must not tend to crack or peel off; it must be adhesive and durable.

Paint and coal tar answer these requirements, and are generally recommended. Coal tar is most commonly used, as it is efficient and cheap. It is, however, a very variable product as regards its composition, and for that reason one hears conflicting reports concerning its value. The injurious effect of the tar can be eliminated by washing the tar with water to remove certain compounds, and its protective properties appear to be improved by mixing it with certain waxes. It is sometimes said that healing of tea wounds will not proceed over tar. As already stated, some wounds will not heal, whether tarred or not, but some of the best healing of tea the writer has seen, and that in Uva, was over a mixture of Skene's wax and tar. Of the paints, a good white lead in linseed oil is probably the best.

In recent years, the use of Bordeaux mixture as a dressing for tea wounds has become prevalent in certain districts. Bordeaux mixture is an excellent antiseptic, but it lacks sticking power. It is washed off by the first heavy rain. For that reason, it is of little use on wounds which take years to heal. On quick-healing, small wounds it can probably be used with satisfaction, but on larger wounds a more durable dressing is required.

Whatever dressing is used, it must be renewed as needed. In practice, it is convenient to renew the dressing after each pruning. A suitable dressing for tea must, therefore, remain intact for two or three years.

Good pruning and the protection of wounds will do much to prevent further infections of wood, though they do nothing towards curing the existing cankers. That is another and difficult problem But, if it is realised that wood rot originates at pruning cuts and that it can be prevented to a large extent by care, there is hope that the young tea now growing in clearings will be kept free from the unsightly cankers so prevalent in many old fields. If this is to be done, the training and shaping of the bushes should be commenced early, before the stems have attained large diameters. Whatever may be the merits or demerits of the system of handling young tea, devised and published by Mr. John Horsfall, it has the advantage of shaping the bushes without making any wounds which will not heal quickly.

In conclusion, the importance of making clean wounds at places where healing is likely to proceed most rapidly is emphasised. Briefly, prune to an eye and leave no stubs. The position of the cut is of more importance than the time of pruning, but if pruning has to be done in unfavourable seasons, stem die backs must be expected. In dry weather when growth is at a minimum, the wound dries rapidly, and the upper buds become involved in the desiccation. The responsibility for the formation of a new shoot then falls on a lower bud, and a second pruning to remove the diebacks becomes necessary. Last but not least, an efficient protection must be afforded to the wounds. The larger the wound and the slower the reparative process the more important becomes the wound dressing.

THE TREATMENT OF THE PORIA ROOT DISEASE.

By

C. H. GADD.

Of the parasitic root diseases of tea, that caused by the fungus *Poria hypolateritia* is the commonest and most difficult to eradicate. The bare areas to be seen in many fields are the direct result, in the majority of cases, of the removal of bushes killed by this disease. Dead bushes may usually be found on the borders of these bare patches; their removal results in an annual increase of each area, unless the further progress of the causal fungus is stopped. Thus, the size of an area often affords some indication of the time the disease has been active.

The infectious nature of the disease is apparent from its continuous spread in ever widening circles. Sometimes the fungus travels more readily in one direction than another, but its progress is always marked by the death of one tea bush after another along its path. That the fungus is highly infectious is too frequently forgotten when the treatment of a diseased area is undertaken. Heaps of dead tea bushes, the roots of which are heavily infected by *Poria hypolateritia*, are frequently to be found lying on estate roads and paths, awaiting transport to the factory or elsewhere for destruction. For obvious reasons, the accumulation of diseased roots on paths is essentially a bad practice, and the source of many new infections.

If, for climatic or other reasons, it is necessary to transport diseased bushes from the site to an incinerator or other centre for destruction by fire, such bushes should be carried in closed sacks. If the coolies are allowed to carry them in open baskets or, what is more commonly the case, in loose bundles, there is grave risk of infectious roots falling unnoticed amongst healthy tea, and there originating new centres of infection.

A RESULT OF THE PORIA ROOT DISEASE IN TEA.

PLATE III.

The first step in the treatment of any root disease is the removal and destruction of all dead and diseased bushes. Unfortunately, there is no means of identifying bushes attacked by the Poria disease by other means than examination of their root systems. Bushes may be severely attacked and yet show no sign above ground that anything is amiss. They may appear in normal health and flush well, but it is only a matter of time before they succumb to the disease.

Bushes attacked by Poria always appear to die suddenly. They may appear quite healthy one week and be dead a week later. When the roots are examined immediately after death, many of the laterals, and often the tap root, are found to be badly rotted. This severe decay is progressive; it is not brought about in a week, nor yet a month. It is probable that several months elapse between the time of first infection and the death of the bush.

In an earlier number of this journal (Vol. 1, pp. 55-60), infection experiments with *Rosellinia arcuata*, a fungus which resembles *Poria hypolateritia* in its mode of attack and general effect in the field, were described. In each experiment, the young tea plants died two months after the fungus was introduced. As the fungus takes two months to kill a well grown seedling, a much longer time must be necessary to destroy a full grown bush. There is no reason to believe that Poria is much quicker in its action than Rosellinia. That the bushes adjacent to a dead bush, killed by Poria, appear healthy is, therefore, no criterion that the fungus is not already well established on their roots.

One other point has to be taken into consideration when attempting to control this disease, namely, the causal fungus can grow freely through the soil. A healthy root need not be in direct contact with a diseased root for the former to become infected. The fungus will grow through the intervening soil from a diseased root, which is used as a food base, to a neighbouring healthy root.

It will be realised from the foregoing that, if all diseased roots are to be removed from an infected area, the uprooting of dead bushes alone is insufficient. If dead bushes only are dug out, and this is the common practice, the infected roots of the adjoining apparently healthy bushes are left in the soil, and the disease causing fungus is propogated on them. By the time these infected bushes are dead and ready to be dug out, the disease has passed to the neighbouring bushes. And so the process goes on, treatment always following the disease but never overtaking it. The removal of dead bushes certainly results in the destruction of large amounts of infectious material and prevents the fungus from producing spores which would be dispersed by the wind, but it does little towards the eradication of the disease from any particular area.

It would appear more economical to remove all infected bushes at the time the dead bushes are dug out, than to wait for some months till they die. It is a difficult matter, however, to ascertain with any

certainty whether all the roots of a tea bush *in situ* are free from infection. The removal of the bush simplifies examination and gives more certainty to the result. For this reason, the bushes immediately adjoining the dead one should be uprooted at the time the dead bush is dug out.

Such a procedure may be objected to on the ground that it may result in an unnecessary destruction of perfectly healthy bushes. In practice, however, it is found that the majority of bushes so removed are heavily infected, and that only a small percentage of sound bushes are uprooted.

The most efficient method of isolating an infected area from the surrounding healthy tea is by means of trenches two feet deep. The trenches must be sited in front of the advancing fungus so that all the infected soil is within the isolated area. The earth from the trench should be thrown on the isolated area. As already stated, it is impossible to determine with certainty how far the fungus has reached beyond the zone of dead bushes, unless the roots of the surrounding apparently healthy bushes are examined. It is a common practice, when dead bushes only are removed, to site the trenches so that two rows of apparently healthy bushes are included within the isolated area. In the majority of cases, the whole of the infected area is included within the circle of trenches. If, however, the fungus has passed the trench sites, the trenches, when constructed, serve no useful purpose.

All the bushes within the entrenched area ultimately die. A few bushes for some unaccountable reason may escape, but such cases are exceptional rather than the rule. The roots of some of the bushes left standing as healthy are infected, and by the time these bushes expire the fungus has passed on to the roots of others. Ultimately, the fungus reaches the trench by which time all the bushes within the isolated area are infected. This process takes several years as a rule. During this time and for some time afterwards, the trenches must be kept open, otherwise the fungus passes the trench and so escapes into the surrounding tea.

As the loss of the bushes within the isolated area has to be accepted, there is no obvious reason why they should not be uprooted and burnt at the time treatment is started. There is then a possibility that the pathogenic fungus may never reach the trench. Under such conditions the trench becomes a last line of defence and not a solitary safeguard. The sacrifice of these bushes, some of which may be perfectly healthy, will result in a loss of crop, but this loss is small compared with that resulting should the disease pass the trench.

It will be realised that the larger the infected area, the longer is its perimeter, and consequently, the longer the line along which the fungus attacks. Control should be attempted as soon as the disease is

observed and while a few bushes only are affected. Unfortunately, the infected areas are now so large on many estates that it is impossible to pass them by unnoticed, and they are growing larger still. The removal of one row of bushes around such large areas constitutes the uprooting of a large number of bushes. Consequently, managers are very reluctant to adopt this method of treatment, although experience has shown that half measures against this disease are useless.

As trenches form such an important line of defence and have to be kept open for very long periods, it is not surprising that the fungus frequently passes them. The continuous reopening of trenches on hill sides becomes a laborious business; they silt up frequently and are apt to be overlooked or forgotten in the press of other work. While silted up, the fungus from infected roots is enabled to reach the far side and so escape into the surrounding tea. Then the whole process has to be begun again. If the isolated area is cleared of all roots as suggested above, the risk of the fungus crossing a silted trench is considerably diminished. To be efficient, however, the trench must be kept open; only where trenches have been correctly sited and kept open have the trenches proved satisfactory safeguards.

In some places, owing to steep slopes or other causes, it is almost impossible to construct trenches, or, when constructed, to keep them constantly open. A bare zone between the infected area and the healthy tea then becomes of considerable importance. In such localities the removal of tea bushes from the margin of diseased areas should be continued until a belt of healthy bushes, one bush deep, has been removed. If dead bushes, alive but infected bushes, and one row of healthy bushes are dug out and destroyed, the soil is freed from all infectious roots and a bare zone is created between the healthy tea roots and the infected soil. This bare zone through which the fungus must grow before it can reach and attack healthy roots takes the place of a trench, though it is not recommended as a substitute except where trenching is impracticable.

No matter how carefully the bushes are uprooted, or how thoroughly the soil is forked over and roots and other similar material are collected, a certain amount of the fungus is sure to be left in the soil. No ready means of destroying this has yet been devised. Some form of soil sterlisation is necessary. If chemicals are used, they must penetrate the soil to a depth of 2 feet but must not render the soil unsuitable for plant growth later. Sterilisation by steam is likely to prove the most efficient means of killing this fungus is the soil. But until some such method is adopted, reliance will have to be placed on starvation for this purpose.

For many years it has been the practise to apply lime to the soil, usually at the rate of 4 lb. per bush as a soil disinfectant in the treatment of root diseases. In the Annual Report of the Tea Research Institute for 1927 (p. 10) the writer stated that the benefit derived from

the use of lime in the treatment of tea root diseases did not appear to warrant its continuance. Since then, laboratory experiments have afforded evidence in support of that observation.

Determinations have been made of the rate of growth of *Poria hypolateritia* in soils to which various amounts of lime had been added. The soils were placed in glass tubes, 12 inches long and $\frac{1}{2}$ inch in diameter. Sterile wood blocks were placed at one end of each soil cylinder and the end of the tubes were plugged with cotton wool. The conditions within the tubes were made as uniform as possible. The water content of the soils was adjusted to 42 per cent before sterilisation. After sterilising the prepared tubes, the wood blocks were infected with *Poria hypolateritia* from pure culture. After some time, the fungus grew freely into the soil. Growth measurements were begun after the fungus had penetrated the soils to a distance of half an inch or more. The amounts of lime used, the moisture content of the soil and other details are given in the accompanying table.*

Growth of *Poria hypolateritia* in soil of different acidities.

Tube No.	Lime Added. Tons per acre.	Sulphur Added. Tons per acre.	Initial pH.	Final pH.	Soil Moisture final.	Growth during period 31-7-28 to 31-8-28. cms.		Mean daily increment during experiment. mm.	
1	—	2	4·07	4·37	37·3	3·5	3·4	1·0	1·0
2	—	2	4·07	4·28	35·9	3·6		1·1	
3	—	2	4·07	4·30	36·6	3·2		1·0	
4	—	-	5·34	5·39	31·5	5·7	6·0	1·9	1·9
5	—	-	5·34	5·31	35·0	6·1		1·9	
6	—	-	5·34	5·46	34·8	6·2		2·0	
7	5	-	6·35	6·24	36·8	7·4	8·3	2·6	2·8
8	5	-	6·35	6·33	36·8	8·9		2·9	
9	5	-	6·35	6·46	32·8	8·5		2·8	
10	15	-	7·66	7·33	34·3	6·8	6·5	2·1	2·0
11	15	-	7·66	7·17	36·5	6·7		2·2	
12	15	-	7·66	7·38	31·3	5·9		1·8	

It is apparent from these measurements and from the photograph reproduced in Plate IV that an application of lime at the rate of 5 tons per acre, instead of having a detrimental effect on the growth rate as would be expected if lime were deleterious to the fungus, resulted in an increased growth rate. The most rapid growth occurred in the soil to which lime at the rate of 5 tons per acre had been added. The growth in soil to which lime at the rate of 15 tons per acre was added was a little greater than that in the untreated soil. Elsewhere, (pp.1-6) it is shown that the heavier application of lime rendered the soil unsuitable for tea seedlings. Reduced growth increments resulted from

* The writer is indebted to Mr. T. Eden for the pH determinations.

PLATE IV.

THE GROWTH OF *PORIA HYPOLATERITIA* IN SOILS OF VARIOUS REACTIONS.

the additions of sulphur. The results of these experiments indicate that lime favours the growth of this fungus in soil, and therefore should not be used in the treatment of this disease.

Laboratory experiments have also shown that *Poria hypolateritia* can exist for several months in soil without any visible food supply such as a diseased root. What this period is, has not been accurately determined, but there is little doubt that it varies with the type of soil and possibly with climatic conditions. The importance of the removal of visible sources of food supply, such as diseased roots and other vegetable tissues, from infected areas cannot be exaggerated.

As the fungus can live for some time independently in the soil, the resupplying of Poria patches for at least twelve months after treatment is inadvisable. This period can be lengthened with advantage. It is not uncommon to find replanted Poria patches with dead bushes around them, indicating that the fungus is still active on the perimeters of the areas. In such cases, the young tea plants normally appear to do well for a few years and then begin to die of the same disease. Some areas have been supplied two or three times without success. It would, therefore, appear inadvisable to replant an area so long as the disease is active. If, however, the ground has lain fallow for at least twelve months and no further death has occurred at the perimeter, it may be safe to replant, but not otherwise.

Poria is a common disease of new clearings; it is often the first to make its presence known. Its eradication from a clearing is less difficult than its extermination from old tea, and for that reason its control in clearings should not be neglected. Dead young plants should not merely be pulled out by hand; the soil should be deeply forked and all jungle roots removed from the neighbourhood of the dead plant. If there is a jungle stump in the immediate vicinity it should be dug out immediately, as it is from such sources that much of the disease originates. The removal of all jungle stumps from a clearing is not a practical proposition, but those in the immediate neighbourhood of dead plants should be suspected and dug out. It is more economical to treat the diseased areas while the clearing is young than to wait till the tea is in bearing, the root systems larger and conditions more favourable for the spread of the fungus.

COMBATING THE TEPHROSIA WEEVIL.

In Java, as in Ceylon, *Tephrosia candida* is in demand as a green manure plant, and in both countries great loss of seed occurs through the attacks of the Tephrosia weevil, *Araeocerus fasciculatus*. In *De Bergcultures*, No. 39 (March 24, 1928), A. A. M. N. Keuchenius describes a method of meeting the attacks of this weevil, which has been practised with success on an area of about 10 acres, planted with *Tephrosia candida* for seed by the Proefstation voor Thee. The chief points of the method are as follows:

As soon as the first pods are nearly ripe they should be gathered.

The pods should be regularly gathered as soon as they turn light brown to brown and the seeds are mottled dark green or grey. In that way the Tephrosia beetle, which in that stage of the pod is present as a larva or pupa, is prevented from developing into the full-grown insect. When the pods and seeds are dried, the larvae and pupae die.

On the plot in question the pods were gathered weekly.

No over-ripe pods must be allowed to remain on the plants, since in that stage the weevil becomes mature and can multiply.

A sufficient number of collectors must be provided, and these must be adequately paid and controlled. The rate of pay in this case was at first 40 (guilder) cents, and afterwards 30 cents, per kilogram of seed.

An area of *Tephrosia candida*, intended for seed, should be widely planted, the rows at least 10 ft. apart, and the seed sown thinly in the row, so that the collectors can do their work properly and can be controlled easily.

No plants which harbour the Tephrosia weevil should be allowed to grow in the vicinity. Among such food plants are *Crotalaria striata*, *Tephrosia toxicaria*, *Tephrosia noctiflora*, *Indigofera suffructicosa*, *Cassia occidentalis*, and, exceptionally, *Crotalaria usaramoensis*.

The foregoing green manures should be removed, or regularly cut, during the flowering and fruiting of the *Tephrosia candida*. It is desirable that that should be done from one and a half months before the flowering of the Tephrosia.

The harvested seed must be well dried, and should not be soft or show a green break when cut across. Good viable seed of Tephrosia should be hard and have a pale yellow, or preferably, white break.

The pruning of the bushes should not be delayed too long after the bulk of the crop has been gathered. Even if the bushes still bear some pods, prune them down to 50 centimetres (20 inches), taking care that the stems are not split.

A dressing of 10 grams ammonium sulphate and 25 grams of double superphosphate per metre (1 oz. ammonium sulphate and $2\frac{1}{2}$ oz. double superphosphate per 10 linear feet) scattered in the row, has given good results as regards early and abundant production of seed.

The method often practised on estates, of allowing *Tephrosia candida* to grow up for seed between the rows of tea, is bad and must be strongly deprecated. A separate seed garden is absolutely essential, if good results are desired.

In the first three and a half months of collecting, the crop of the seed garden (10 acres) was 300 kilogrammes of seed per hectare (270 lb. per acre) and it was estimated that the total crop would be double that. The percentage of seed damaged by weevils varied from 1·4 to 3·3, while the germination was 88 per cent.

T. PETCH.

NOTES ON GREEN BUG *(COCCUS VIRIDIS)* GREEN.

In a recent number of *De Bergcultures* (3rd year, No. 17, pp. 423—429, 1928), Dr. H. Bergemann has published an interesting account of the Green Bug in the Dutch East Indies. Although coffee is the host-plant referred to, the article contains several points of interest to the tea planter.

Quoting freely from the work of Van der Goot, the author states that the whole life history of the bug occupies at least 65 days, and that, under favourable conditions, the adult bug is capable of living for two months or more. Hardly 3 per cent. of the young bugs complete their life-history; thus from the 700—800 eggs laid by one female, hardly 40 of the offspring come to perfection, and often not more than 20—25. But even so, a single individual may give rise to 25 in two months and 600 in four months.

Infection of fresh areas is performed by the young bugs, which, after hatching, wander about from tree to tree before settling down. The author believes that the chief agents which assist in their spread are the wind, man and animals. From replies to enquiries sent to infected estates, it was found that, in the great majority of cases, Green Bug is most prevalent during periods of drought. In Ceylon, where Green Bug flourishes only in regions receiving one monsoon, it has been observed that dry periods with occasional showers of rain are most favourable for the occurrence of this pest.

As is commonly the case with scale insects, Green Bug is attended by various species of ants which feed on the liquid excretion of the bugs, and at the same time protect them from their natural enemies. The results of this interference by the ants are that the bugs breed more prolifically, the death rate is lower and the attacks of parasitic wasps are greatly reduced. In Ceylon, however, ants apparently do not play an important part in the life of Green Bug.

Various fungi attack the scale, the commonest of which is the white mould *Cephalosporium lecanii* Zimm., particularly during the West Monsoon in Java. The same fungus also affords an important check of Green Bug in Ceylon, mainly during the N. E. Monsoon.

The two principal forms of control carried out in Java are the application of chemical substances to the bugs and the destruction of the ants protecting the scales. Chemical control appears to be frequently ineffective, owing partly to the fact that the spray kills not only the bugs but also their parasites and other natural enemies. From answers to enquiries sent to estates, it is evident that the greatest measure of success is obtained by combining the control of the ants with the destruction of the bugs.

S. STUART LIGHT.

CASSIA MULTIJUGA.

In Java, the choice of trees for shade and green manure lies between *Albizzia falcata*, (*A. moluccana*), *Deguelia microphylla* (*Derris microphylla*), Dadap, and for high land, Acacia. Albizzia and Deguelia are often planted in alternate rows; then, the former is regarded as temporary and the latter as permanent shade.

Albizzia is subject to many pests, particularly the caterpillar of the little yellow butterfly (*Terias silhetana*). Its brittle wood renders it liable to severe wind injury. Deguelia suffers less from pests and withstands wind better, but its growth is slow and it gives but thin shade with proportionally little leaf fall. The dadap suffers much from the attacks of caterpillars and beetles, and does not thrive on poor soils. Acacias are considered of little value on estates below 3,500 ft.

Mr. G. Koch of Sindang-Panon Estate, recognising the need for other suitable trees, has experimented for the last four years with *Cassia multijuga* as a shade tree for tea, and has described his experiments in *De Bergcultures* of September 8th, 1928, pp. 254—257. Although *Cassia multijuga* has been grown in Ceylon as an ornamental tree since its introduction in 1851, its possible value as a shade tree for agricultural purposes has apparently not been determined. Mr. Koch's experiment may, therefore, be of interest here.

The seeds were sown in September, 1924, two seeds to each hole, four inches apart, in nurseries. Before sowing they were soaked overnight in water. By the end of 1925, the plants had attained a height of about 8 feet. In January, 1926, they were pulled from the beds, cut back to 3 feet, and used in a tea clearing.

Sufficient planting material for four rows, 40 feet apart was available. In the first row, holes were cut 13 feet apart and $1\frac{1}{2}$ feet deep, but in the remaining rows a distance of 20 feet was allowed between the holes. For comparison, two year old Deguelia stumps were similarly planted between the rows of Cassias. The remainder of the clearing was planted with alternate lines of Albizzia and Deguelias.

By May, 1927, i.e. $1\frac{1}{2}$ years from planting, the Cassias had a uniform spread of 20 feet and so touched each other in the rows. The Deguelias had a spread of only 6 feet, and the Albizzias 11 feet. Not a single death occurred amongst the Cassias, whereas 20 per cent. of the Deguelias and 12 per cent. of the Albizzias failed to strike.

The soil conditions of the clearing were not uniform; the higher ground had the poorer soil. Very little difference could be observed between the Cassias on the different soil types, whereas the Deguelias on the poorer soil were more dead than alive, and the Albizzias showed distinct growth differences, the better growth occurring on the better soil. From these observations it is concluded that *Cassia multijuga* can thrive well on poor soil, and is not dependent upon rich soil for rapid growth.

The Cassias provided a greater leaf fall and suffered less wind injury than the Albizzias. The latter fact is attributed to the tougher wood of the Cassias. The tea plants under Cassia did better than those under Deguelia.

A second experiment was started in January 1927 on an area of approximately 7 acres. Cassias and Deguelias were planted as before in alternate lines and at the same planting distances. Both species were of the same age, about one year old. By June 1928, the Cassias touched each other in the lines and stood about 15 feet high. The Deguelias in comparison formed a poor cover. Less than one half per cent. of the Cassias failed, whereas 19 per cent. of the Deguelias died.

Cassia multijuga, when grown from stumps, has a tendency to form many stems; with one main stem it approximates most nearly the ideal shade. As the tree naturally forms wide spreading branches, the desired parasol shape may be obtained by cutting away the lower branches only and without any top pruning.

Trials with this tree were also made by Mr. H. A. Hulshoff at elevations of 3,500, 4,300, and 5,000 feet. One year old stumps were used. He reported that, after 12 months, the trees at 3,500 ft. and 4,300 ft. were growing vigorously and developing well; their height was then 12—15 ft. At 5,000 ft. the growth was somewhat slower.

The advantages claimed for *Cassia multijuga* are its very rapid growth, its great spread giving a regular light shade and abundant leaf fall, its apparent freedom from pests, its ability to withstand wind owing to its tough wood, and its small requirements regarding soil fertility.

Macmillan in his *Tropical gardening and planting* describes *Cassia multijuga* as "a slender, brittle, quick growing tree." In Ceylon, this tree is very susceptible to wind injury owing to the brittle nature of its wood; in this respect our experience differs from that reported from Java. It grows well at Peradeniya and flowers abundantly, but rarely produces seed there. At Anuradhapura, however, possibly owing to the drier climate, it bore fruit abundantly in the former botanic gardens.

C. H. GADD.

THE TECHNIQUE OF FIELD EXPERIMENTS.

R. O. Iliffe and B. V. Nath, in a recent publication entitled *The conduct of field experiments* (Dept. Agric., Madras Bull. No. 89), have reviewed the present position regarding the objects and design of field experiments. Its aim is to provide guidance for experimenters in the conduct of field experiments, by "discussing the aspects of experiments in general—showing how experiments should be laid out and the various precautions which should be taken—how probable error should be estimated—how results should be interpreted."

The main features of field experimental technique are dealt with in three parts, (I) General principles, (II) Examples of design (III) Interpretation of results. A brief section on future work follows. There is a lengthy bibliography to which, however, the references in the text are only occasional. The authors present the pamphlet as a compilation from numerous sources; they are, therefore, not responsible for the methods described. Their responsibility is chiefly in the emphasis that they place upon the various techniques.

The first section discusses the difficulties encountered in even the smallest and simplest experiments, and deals at length with questions of edge effect, plot shape and size. The authors are alive to the problem of soil heterogeneity, and are insistent upon the need for combating it. They make an important point in pleading for a "well planned field experiment as a necessary adjunct to a well thought out line of inquiry."

We would however dissent from a number of their conclusions. The authors are of the opinion that more than five replications are unnecessary; but this will surely depend on the nature of the land, the crop, and the standard of accuracy necessary to answer the problems contemplated. The statement of probable errors of experiments on pages 7 *et seq.* provides more than one instance where the error from five or more replicates is still disconcertingly large. With regard to these same errors, it is noteworthy that they are not all of equal validity. Thus, some are obtained from single plots over a period of years. Such an "error", if low, merely shows that over several seasons the response of the various plots has been consistent. It is not a random error at all, and is no safeguard against the very probable contingency that the initial fertility of one plot was greater than its neighbour in the comparison.

The authors are in favour of interpreting results and allocating plot positions by the results of a one or two years Uniformity trial. As against this, there is an ever increasing body of evidence being published to show that the heterogeneity contour for annual crops changes from year to year.

Dealing with experimental method, they say "only one factor, or one range of the same factor should be studied at a time. If information is sought concerning a number of other factors, each separate factor should be studied in a separate experiment planned for the purpose." Recent work at Rothamsted has shown otherwise. Moreover, it is often the interplay of two or more factors which is of chief interest and importance. It is, however, only right to say that the exact treatment of multivariable experiments has only recently been published, probably, since this bulletin was written.

The second portion of the bulletin is largely devoted to descriptions and recommendation of plans of experiments carried out by the writer of this review at Rothamsted. These formed part of a comprehensive programme of research into field experimental technique on the part of the Statistical and Field Experiments Departments. In the course of these investigations, these departments tried out a number of designs including ordinary chessboards, balanced chessboards and alternating strips, but finally discarded as unsatisfactory from the statistical and field point of view, all except the randomised experiments interpreted by the elegant "Analysis of Variance" recently described in the Tropical Agriculturist for August. It is unfortunate that in borrowing from the published description of these experiments, the authors should have neglected the culminating design, and should have advocated only those which have been abandoned as unsatisfactory. The weakness of these preliminary designs was set out in the original publication as being due to "the fact that the errors though certainly small are not definitely known; they cannot be calculated accurately."

The authors are content to say "we have reviewed the recent literature advocating randomization in selection of plots under trial, but we consider that much more must be said on this subject before we can confidently recommend the adoption of randomization for general use." This view can only be the result of an inadequate appreciation of the fundamental basis of all statistical computation—the random sample. The impression remains that in this matter the bulletin emphasizes the shadow rather than the substance of recent researches into plot technique.

T. EDEN.

REVIEW OF MONTHLY REPORTS OF THE SCIENTIFIC STAFF, TEA RESEARCH INSTITUTE.

The following review relates to the progress reports for September, October and November, 1928.

The Mycologist has made further analyses of the wood of tea roots to determine the amounts of starch and sugars in healthy and 'Diplodia' bushes. So far, the results confirm the observations from qualitative tests already reported.

Failure to recover from collar pruning is, in many cases, the result of a deficiency of food reserves within the roots. Such failures are likely to occur in fields where deaths commonly occur after normal pruning. The presence of starch within the roots, however, is not a sure indication that the bushes will recover rapidly, if collar pruned. A number of bushes, which were collar pruned in July, were examined in the middle of November, as by that time growth had not started. The roots were alive and healthy; no die back had occurred from the cut, and starch was present in all the roots. The reason for the delay in growth is not apparent, but so long as the roots remain alive there is a possibility of new stems being formed. The physiological processes which culminate in new growth after pruning are complex and dependent on several factors, one of the most important being the availability of reserve foods.

Very few outbreaks of the Cercosporella leaf disease occurred during the South-West Monsoon this year, and these were relatively mild. Fructifications (perithecia) similar in appearance to those obtained in pure cultures of the fungus *Cercosporella Theae* were found on one occasion on dead tea leaves killed by this disease. Unfortunately, no spores could be found, so accurate identification was not possible.

A new leaf disease of mature tea has been found in several fields of an estate in the Kalutara district, and with which was associated the fungus *Corticium vagum* (*Rhizoctonia solani*). This fungus has been reported on tea only once previously, and then it was associated with a disease of seedlings in the same district. The field evidence strongly supports the conclusion that *R. solani* is the causal fungus but inoculation experiments on tea seedlings in the laboratory at Nuwara Eliya failed to give positive results.

The fungus is quite common in Celyon soils, and is well known as a disease of seedlings of many species. For some years it has been known to be the cause of a serious leaf disease of Vigna (*Dolichos Hosei*) in the low-country. On tea, the fungus reaches the leaves via the stems, along which it grows as fine strands, and it causes no injury until it spreads over the leaves as a fine weft. In this respect the disease resembles that known as Black rot (*Corticium invisum*).

Complaints have been received concerning the poor germination of tea seed from certain estates. Investigations have shown that the seed is healthy, and that germination is delayed by some character of the shell, its hardness, thickness or impermeability to water, rather than by any fault in the germ itself. When the coats (shells) are removed from the seeds, the rate of germination is greatly improved.

Experiments have been made to determine the rate of growth of *Poria hypolateritia*, the cause of a serious root disease of tea, through soils of different reactions. The experiments demonstrate that an application of lime at the rate 5 tons per acre result in an increase of the growth rate of the fungus, and even 15 tons per acre has no beneficial effect. There is no reason to believe that lime has any effect in the treatment of root diseases other than the change it causes in soil reaction. In this case, the change proved beneficial to the fungus. In view of this experiment and of the observations made in the field, the use of lime in the treatment of this disease is not recommended.

The soil reaction values of the above experiment were determined by the Soil Chemist. They ranged from 4 to 8 on the pH scale, *i.e.* from conditions of great acidity to that of pronounced alkalinity, agriculturally. The general tendency was for the fungus to move the reaction value to a position of equilibrium on the acid side of neutrality. The part played by fungi in the decomposition of vegetable residues is well known, and these results indicate how the reaction of partially decomposed organic residues tends to be controlled in the process.

Further progress has been made in the basic exchange studies of the soils. The rapid rate at which losses of exchangeable bases occurs from soils under tropical conditions is illustrated by the follwoing observations. Two soils, which differed only in that one had twelve months previously received a ton of lime per acre, showed no difference, either in the total quantity of exchangeable base or in the quantity of exchangeable calcium. Since neither soil contained free calcium carbonate, the results show that within the period stated the whole of the lime had been removed from the surface layers of the soil, that all calcium ions which had entered the soil colloid complex as a result of the application of lime had disappeared, and that the original equilibrium within that complex had been re-established. This observation possibly affords an explanation of the tentative conclusion previously reported, viz., that calcium does not supply such a large proportion of exchangeable bases to the total sum, as is usually the case in well-conditioned temperate soils. The heavy rainfall to which tea soils are subject offers an adequate explanation of this heavy loss.

In order to extract as much information as possible from the leaf samples obtained from the Uniformity Trials, the soil chemist has undertaken the analysis of these for the two plant nutrients, potash and phosphate. The nitrogen determinations are made by the Biochemist. The complete data are of interest to both chemical divisions. The results will give indications of the rates of nutrient uptake which may be correlated with yield increments and with climatic conditions. No importance attaches to the actual gross amounts of the nutrient elements taken from the soil as such quantities have little bearing on the amounts of these substances required as manures, but a study of the rates of uptake has a real bearing on manurial practice. Such data are not available in the Ceylon literature.

A sample of a highly adulterated ground fish product, sold as manure locally, was found to contain 50 per cent. insoluble material, mainly sand. The nitrogen and phosphate contents were so low as to make the manure unsatisfactory and expensive in comparison with the standard article. In the absence of guaranteed analyses, the buyer has no redress; as the buyer of such supplies is normally the village agriculturist, the necessity for legal protection is apparent.

Work has been continued on the Uniformity Trial; six pluckings have been made in the three months.

The Biochemist has continued his investigations of the seasonal changes in the green leaf as plucked, samples for analysis being obtained from the plots of the Uniformity Trial. The onset of North-East Monsoon conditions has resulted in lower figures being obtained for the components estimated, though the different components are not affected equally. The effect of continuous wet weather appears to be cumulative as the soluble matter of the leaf of successive plucks tends to decrease continuously. The same tendency has been noted regarding the total nitrogen of the leaf, the nitrogen in the extract, and the non-tannin portion of the extract. The tannin content of the extract shows a big variation from pluck to pluck, but the tendency to become uniformly less during spells of wet weather is not so evident. Confirmation of these observations will be obtained by regular analyses such as are being made.

Progress has also been made with the investigation of the changes which occur during withering. During withering, not only is water lost from the leaf, but a part of the solid matter also disappears as a result of the respiratory changes which take place. The amount of solid matter lost in this way is appreciable and must be taken into account when interpreting the results of chemical analyses.

It would appear from table 1, column 1, that an increase of soluble material occurred in both samples of leaf during withering. When the analyses are corrected for respiratory losses (column 2), it becomes evident that no real, appreciable increase in quantity of the extractable materials had taken place.

Table I.

	Extract Uncorrected.	Extract Corrected.	Alcohol Soluble.	Alcohol Insol.	Tannin	Nitrogen in Extract.
	%	%	%	%	%	%
I. Fresh Leaf	38·5	38·5	35·88	2·92	14·65	1·64
Withered 24 hours.	40·05	38·9	34·80	4·10	14·80	1·74
Withered 48 hours.	40·34	38·8	34·60	2·20	15·00	1·83
II. Fresh Leaf	39·46	39·46	36·22	3·24	14·95	1·64
Withered 2 days.	41·62	40·05	35·35	4·70	15·20	1·74
Withered 3 days.	40·82	39·60	35·00	4·60	14·80	1·81

In the same table, figures, corrected for respiratory losses during withering, are also given of the alcohol soluble and alcohol insoluble substances, the tannin, and the nitrogen content of the extract. From these it is apparent that the material soluble in alcohol diminishes in quantity during withering, whereas the gummy substance insoluble in alcohol increases in amount. In the two instances given, the increase of the alcohol insoluble material amounts to 38 and 45 per cent. respectively. An increase of tannin also occurs during the first two days of withering, but if this process is prolonged to the third day, a decrease occurs.

The amount of nitrogen in the extract also increases during withering. This increase probably results from hydrolysis of protein substances with the formation of amino acids. A prolonged wither, particularly at high temperatures, should therefore be avoided, as a degradation of protein substances is liable to sour the leaf and produce objectionably odoured substances. This, however, is a matter which will be investigated further.

The Entomologist has been occupied mainly with the breeding of the egg parasite of Tortrix. The egg of the paddy grain moth has not proved a successful medium on which to raise the parasite, so a reversion is being made to the eggs of the maize moth.

Considerable difficulty is being experienced in increasing the stock of parasites at a satisfactory rate. To be of any use in controlling Tortrix in the field, parasites will have to be liberated by the hundreds of thousands daily. Before this can be done, a laboratory stock has to be raised, and each generation must be at least twice as large in number as its predecessor. The latter requirement is essential in order that half of each day's out-turn may be liberated without causing a depletion of the stock colony. As yet, this standard has not been maintained but it is hoped that the use of the egg of the maize moth instead of that of the paddy moth will result in an improvement in this respect.

It has been demonstrated that the parasites reared on grain moth's eggs will attack the eggs of the Tortrix moth. In the test, several Tortrix egg masses were parasitised to the extent of nearly 100 per cent. If the parasites can be raised in sufficient quantity, this promises well for a possible effective control by this method.

Nettle grub has been reported from the Udapussellawa district; the evidence indicates that the insects have migrated from the Badulla district.

Trials of various proprietary insecticides on Tortrix larvae have been continued. Tests with poison dusts have been carried out on Bag worms and a species of Geometrid caterpillars found to attack Albizzias.

C. H. GADD.
Acting Director.

THE FIRST CONFERENCE OF THE TEA RESEARCH INSTITUTE OF CEYLON.

The first conference of the Tea Research Institute of Ceylon was held on March 11th 1929, in the Board Room of the Department of Agriculture, Peradeniya. Mr. R. G. Coombe, Chairman of the Institute, presided.

THE CHAIRMAN'S ADDRESS

Before asking Mr. Whitehead to read his paper, I feel that this being the first, and I trust by no means the last, appearance of the Tea Research Institute in public, a short history of the Institute, what it has done and what are its hopes for the future, may be of interest. Before going any further, I should like to express, not only on my own behalf but also of those present today, our regret that His Excellency the Governor has not been able to be present at this our first conference. Other public engagements have necessitated his being elsewhere. We also regret that the President of the Ceylon Association in London is not here today, also our Rural Member, the Hon. Mr. George Brown and the Chairman of the Ceylon Estates Proprietary Association.

The Institute has been established for just over three years, during which time the scientific staff has worked in temporary quarters in Nuwara Eliya. Many and varied difficulties have been encountered by the Board in their efforts to secure an estate suitable for a main Research Station and Headquarters for the staff.

The best part of 50 estates was considered before negotiations were opened with the proprietors of the estate we have recently purchased in the heart of one of our best up-country districts, Dimbula.

The thanks of the tea industry are due to the Anglo-Ceylon and General Estates Co., through its Chairman, our old friend, Sir Edward Rosling, for their public-spirited action in agreeing to dispose of one of their up-country tea properties to us, and thus furthering the interests and work of tea research in this Colony.

The total extent of St. Coombs Estate is said to be 415 acres, of which 185 acres are tea in bearing and 93 acres young tea. Of the balance, approximately another 100 acres are considered suitable for tea. The remainder, after all buildings have been erected, will be planted in fuel, which is a very scarce commodity at the moment. The Board's intentions are to develop and work the estate on commercial lines, setting aside from 50 to 70 acres for experimental and research purposes.

We are fortunate in having secured as our Visiting Agent and Adviser the services of Mr. J. W. Ferguson, whose long experience of estate management in Dimbula is second to none.

It has recently been decided to appoint a sub-Committee comprising the Director of the Institute, the Agricultural Chemist, the Visiting Agent, the Superintendent of the Estate, and two planters, not necessarily members of the Board, to decide exactly what experiments are to be carried out on the area set aside for that purpose and the policy generally to be adopted. As soon as this main Research Station is fully developed and equipped, it is the intention of the Board, if suitable land can be secured, a by no means easy matter in these days, and if funds are available, to open sub-stations of about 40 acres in extent, in other parts of the tea-growing area where climatic conditions and elevation are different from those to be found on the main station.

A question may be fairly asked: How is it intended to finance the purchase and equipment of the estate as well as to carry on our research work? Until we purchased the estate, our sole source of revenue was from the Cess of 1/10 of a cent. per pound on all tea exported from the Colony. Our income from this source annually is from two to two and a third lakhs of rupees.

The question of how the money required for the purchase and equipment of the estate was to be raised was very carefully considered by the Board, and it was decided to approach Government and ask for a loan of one million rupees, in preference to arranging a Debenture issue. The loan which bears 6 per cent. interest was duly arranged, and our thanks are due to the Colonial Treasurer (the Hon. Mr. W. W. Woods), for his valuable advice and ready assistance, and to the Legislative Council for granting the loan.

The terms of repayment are based upon what is known as a fixed annuity, payable in 25 years by annual equal instalments of Rs. 78,227.

Some surprise may be felt at the size of the loan. We have had to pay what at first sight appeared to be a fancy figure for the estate. Our advisers, however, assure us that when fully developed this will not prove to be the case. At present we have no factory or superintendent's bungalow. Both these buildings have recently been started and, it is hoped, they will be finished within six months.

Funds are also required to develop the immature area and that still to be planted, as well as for sundry other buildings, such as Lines, Teamaker's house, Office, etc.

The Board straightaway decided that the factory must be built on the most up-to-date lines. We are indebted to Mr. Whitehead, who will shortly tell you more about this building, and to the Colombo Commercial Co., for the care they have taken in designing the lay-out

of the building. Our thanks are also due to Messrs. Tangye Ltd., Messrs. the Colombo Commercial Co., Messrs. Davidson & Co., and Messrs. Walker, Sons & Co., Ltd. for the generous reductions allowed on the cost of the factory itself, as well as upon the various machinery to be installed therein.

Turning to the Research side, the Board has under consideration the following comprehensive building programme for its main research station and accommodation for the staff:—Laboratories and Head Office, Director's bungalow, five bungalows for Senior Officers and the same number for the subordinate officers. The amount at present in reserve being the accumulated balance and interest from the Cess, will not permit of the whole of this programme being carried out at once. It is, therefore, proposed to spread it over three years.

Due to unforeseen difficulties mainly in connexion with the plans, it is feared that it will not be possible to commence operations in this direction until September. We hope then to arrange for the work on all except one of each type of bungalow to be carried out without a break.

That, gentlemen, is our history to the present time. I feel however that I cannot sit down without making some reference to our staff. We are unfortunate in having lost the services of our first Director, Mr. T. Petch. The work he put in during the $2\frac{3}{4}$ years he was with us has given us a start, the value of which cannot be easily assessed. His task and that of those officers working under him has not been an easy one because of the makeshift conditions under which they have worked. Many important problems are being investigated, which, in due course, will be published through the medium of our own journal, "*The Tea Quarterly*." Given time and opportunity, I personally am satisfied that our staff will more than justify its existence and prove a boon to the tea industry of this Colony.

MODERN TEA MANUFACTURE—CEYLON RESEARCH INSTITUTE FACTORY.

By

F. J. WHITEHEAD.

The history of the development of the tea industry in Ceylon, is not unlike that of most industries. The beginning is obscure, existing buildings and simple apparatus were made to serve, obvious improvements and innovations suggested themselves as time went on, until today everything connected with the industry has become specialised.

The rate of progress is generally dependent upon a varying number of factors, the chief of which are perhaps collaboration and competition.

Now although there has been little organised collaboration with regard to tea manufacture in Ceylon, the planting community is so compact, and so well organised in itself, that it is quickly irrigated with any new idea or improvement. What has been found to be good in one factory, soon becomes known throughout Ceylon plantations.

Tea buyers' discrimination, resulting from a falling market, has always been a starting point for vigorous measures for the improvement of quality of output.

Today Ceylon holds an enviable position among the tea-producing countries, in spite of the handicap of a comparatively poor soil and the hilly nature of its tea-producing areas.

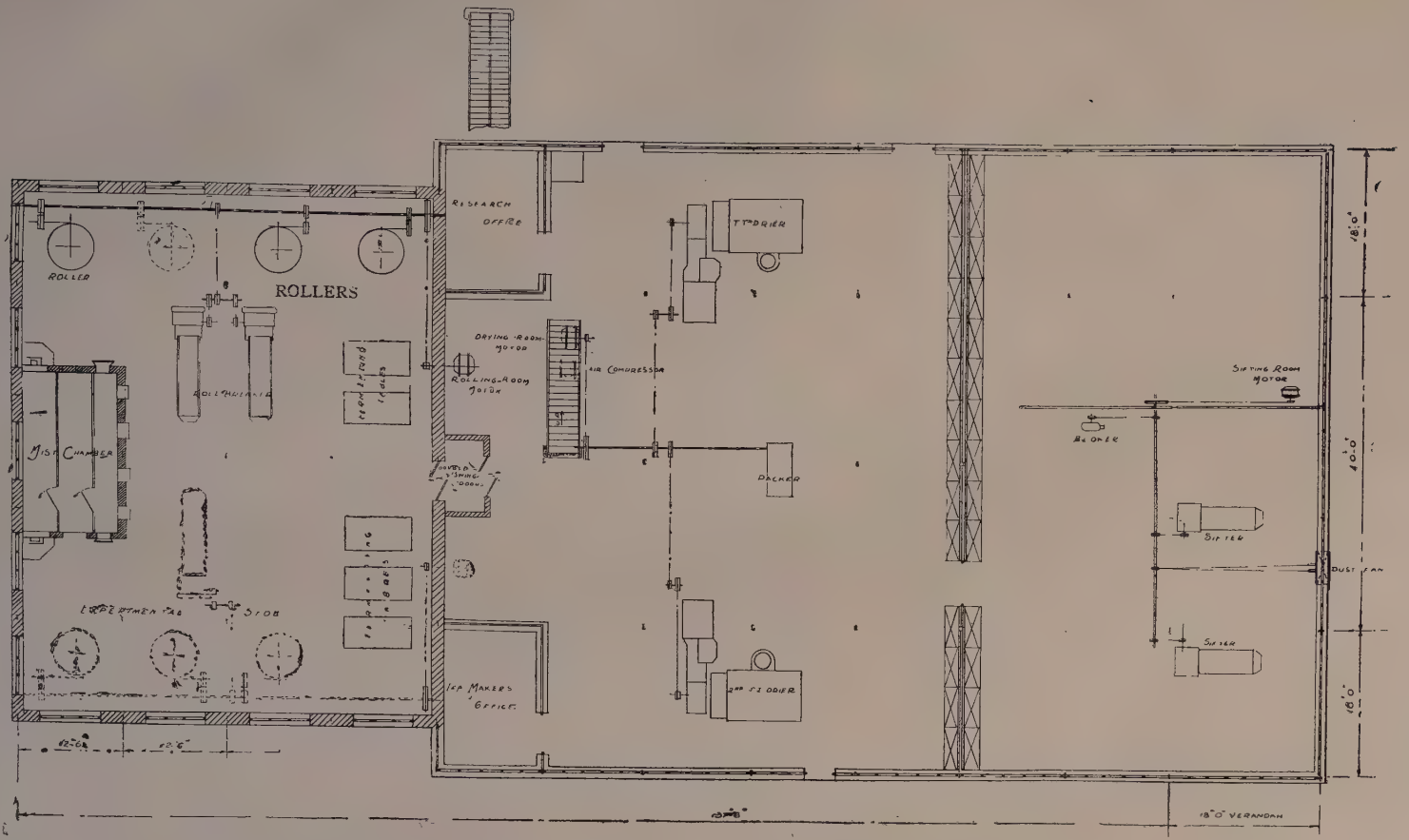
It would serve little purpose for me to describe the old converted coffee store, or to trace the steps of factory design and manufacturing methods, down to the present day.

Tea factories may today be classified as old converted coffee stores, semi-modern factories and up-to-date factories. It is with the latter I wish to deal, and particularly the factory designed for the Tea Research Institute.

In outline and general design, the building does not differ greatly from modern practice.

The rolling room is built in on all four sides with masonry walls to roof and ceiling levels to exclude heat. Venetian windows and insulated roofs are provided for the same purpose, and means of cooling, ventilating and humidifying the rolling room atmosphere are provided, and to this I shall refer later. The arrangement of machinery is orthodox, except that provision has been made for electrical driving, and this enables one side of the rolling room, driven with independent and variable speed power, to be given over for research purposes.

Regular manufacture will be carried out on one side of the rolling room, and experimental work on the other, and as two separate motors are to be used, neither side will interfere in any way with the other.



TEA RESEARCH INSTITUTE FACTORY (Ground Floor Plan.)

PLATE I.

It may be remarked that no separate room has been set apart for the fermentation of green leaf. The reason for this apparent omission, is that it has been considered wiser to treat the whole of the rolling room, as though it were, as indeed it is, one large fermenting room. The fact that leaf begins to ferment as soon as it enters the first roller is generally acknowledged, and so, for any investigations into the control of fermentation to be thorough, the conditions under which this process is carried on, must be controllable throughout the entire process, and not merely confined to a small proportion of the total time.

The method of treating the rolling room atmosphere may be of interest.

For some considerable time, we have been experimenting with humidifying apparatus, and the greatest measure of success has been obtained so far by using what is termed a mist chamber, adopting the plenum system of ventilating, treating a large quantity of air, washing, cooling and humidifying it and maintaining a very slight degree of air pressure in the rolling room above that of the outside atmosphere. Actual tests, using an exactly similar equipment to that shown on the Research Factory plan, have been witnessed by some members of your Committee, and the results obtained were considered very gratifying indeed. Rolling room temperatures have, in very dry weather, been reduced to within one and two degrees of the wet bulb temperature, without any signs of free moisture being apparent in the air.

At the same time the quantity of air so treated was sufficient to change the entire rolling room atmosphere, approximately every 2 minutes, so that, as I have already mentioned, we have been able to cool, ventilate, and humidify, at the same time.

The methods adopted are extremely simple, and in this instance have been made widely variable for experimental purposes. I would like to acknowledge the valuable assistance given by Mr. W. J. Rettie in this connection. This gentleman allowed the installation in his factories of different types of humidifiers, permitting the test of one type against another. His carefully-kept records of results have been extremely helpful, in arriving at a successful design of humidifying chamber. The objects aimed at in the humidifying of rolling rooms are, first, to reduce the working temperature in hot dry weather, second, to prevent drying of green leaf during rolling, sifting and fermenting, thus obviating the necessity for producing lighter withers in hot seasons and harder withers in the wet seasons.

To obtain regular high quality of output, in the production of any manufactured article, standardisation of every process is essential. By means of this mist chamber it should be possible to control the degree of evaporation to which green leaf, in the rolling room, must be subjected for several hours. This should enable the process of

withering to be standardised and it is hoped that experiments in withering, rolling and fermenting will no longer be vitiated through the varying climatic conditions which occur throughout the year.

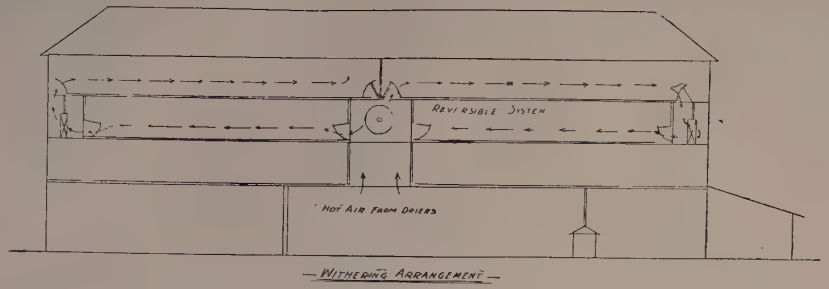
The drying and sifting rooms call for no special comment, each is to be driven by a separate, electric, variable speed motor and here again, experimental work can proceed, without interfering with normal manufacture.

The withering lofts (3 in number) are 137½ ft. long, 40 feet wide and 8 feet high. The two latter dimensions are comparable with those of most Ceylon factories, and wire edge tats of the Austin Dickson type are to be provided. The artificial withering equipment is unique, since provision has been made for conducting artificial withering by several different and distinct systems.

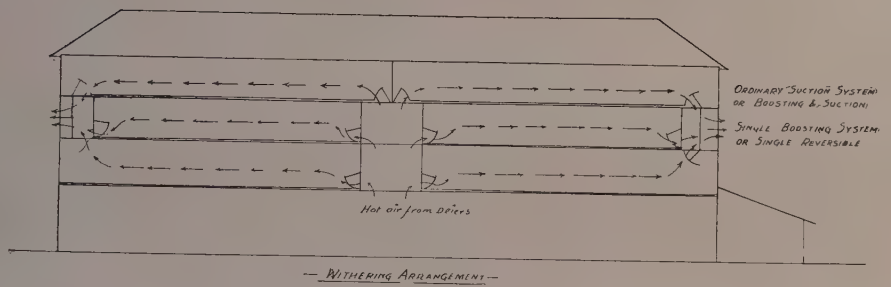
The commonest system in Ceylon is known as the suction system, in which suction fans are placed at the ends of the lofts and arranged to draw air from a central bulking chamber and to exhaust it to atmosphere. The central bulking chamber is placed over the drying room, and receives the hot air from the driers, and also cool air from the atmosphere.

This system suffers from several defects, the chief of which is the position of the fans. The heated exhaust air from the tea driers is far too hot to do anything but scorch any green leaf with which it comes in contact, and so must be diluted with a large proportion of cooler air. This dilution, or bulking, of hot and cool air is very important, and requires to be done in exact proportions according to the temperature and humidity of the atmospheric air. If the atmospheric air is very cold, and of a relatively high humidity, much less will be required for bulking down, than will be the case when outside temperatures are higher, and relative humidities are lower. Now, because the fans are placed at the most distant points from the bulking chamber and are baffled by the end partitions and by the withering tats, it cannot be expected that any exact proportioning of hot and cool air will be possible, or that any degree of even bulking will take place. Consequently artificial withering, with end suction fans only, is found to produce very uneven and often patchy artificial withers. Unevenness of wither is a fault, the full significance of which is seldom realised. I have measured artificial withers, in a loft which varied from 40 per cent. at one end to 70 per cent. at the other; the factory records showed 55 per cent. which is of course the average of the two extremes, and everyone was happy. Yet there was very little leaf in that loft really well withered, and a great deal of the leaf was spoiled.

It is therefore very evident that average withers cannot be relied upon, and that no artificial wither but an even one will ever indicate what degree of artificial withering is the best.



I.



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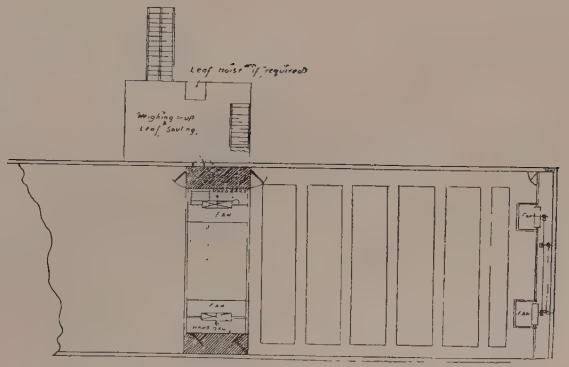


III.

WITHERING ARRANGEMENTS.

I. Reversible System.

II. General System.

III. Arrangement of Fans.

PLATE II.

With a view to overcoming the defects in the suction system, we introduced, some two years ago, a new system, known as the boosting system.

In this, fans are placed at the central bulking chamber, and means are provided for mixing hot and cool air in any proportion. The mixed air is further delivered into the lofts at its maximum velocity, and there is no stagnation of hot air at the near tats.

It was soon realised, that very large quantities of cool air were required to bulk with the hot air from the driers, if scorching of leaf was to be avoided, and very simple arithmetic will show, that if loft temperatures are not to exceed atmospheric temperatures by more than 10°F., the central pressure fans must be able to propel 3 to 4 times the quantity of air given out by the driers.

It should be realised, that when say 55 per cent. withers are required, nearly 50 per cent. more evaporation takes place in the lofts than in the driers, and that all the available heat from the tea driers can be usefully employed, provided such a heat is used at a sufficiently low temperature obtained by adequate bulking.

The introduction of central pressure, or boosting fans, produced cooler and more even withers than the suction system. A combination of the two systems further improved matters, but ultimately a point was reached when it became apparent that the nearer a perfectly even artificial wither was approached, the more costly did the process become. In any loft of appreciable length, withering, with air flowing in one direction only, can never be quite even.

The air must fall in temperature and rise in humidity in its passage through the loft, so long as any evaporation of moisture from the leaf is taking place.

The degree of temperature dropped, from end to end of a loft, can be taken as an indication of the degree of the unevenness of the wither, it can also be taken as an indication of the amount of evaporation or withering being done. These two statements being granted, even withering, with air flowing in one direction, becomes an impossibility.

The discovery and realisation of this important and disappointing fact, led to the invention of a fourth system known as the Reversible System, the patent rights of which are held by the Colombo Commercial Co. Ltd. In this system the central pressure and mixing fans are retained, but the end fan arrangement is altered considerably, and made to reverse the flow of air in the lofts. Any unevenness of wither, caused by the flow of air in one direction can be balanced by reversing the direction of the air, and causing equally uneven withering in the opposite direction. The first reversible system was installed in Hindagalla Factory in the Badulla district about two years ago.

In the reversible system of artificial withering, tempered air is propelled along one half of any loft, and returned through any other half loft, when it escapes to atmosphere. By simple means, the flow of air through the two half lofts can be reversed, and any unevenness produced in one direction is cancelled by that caused in the reverse.

In uni-directional withering, it will be readily realised that for any moderate degree of evenness to result, the air escaping to atmosphere at the distant end of the loft, must be very little more humid than it was at the centre of the loft, and therefore the escaping air must be capable of further useful work. This has inevitably resulted in a large waste of useful and costly heat. By using this air, in making it traverse a second half loft, a saving in cost and time is effected. Whatever withering is obtained in the second half loft is a clear gain, because no more power and heat are required. To illustrate this, let us assume the air starts at the centre of one half loft having a hygrometer difference of 8°F, that by the time it reaches the end of the loft this difference has fallen to 5°F., and that a further drop to 2°F., results by the time it is expelled to atmosphere at the end of the 2nd half loft. We have now used the heat of the air to such an extent, that the air is capable of doing no further useful work.

On reversal of the air flow, the hygrometer differences are also reversed, and the leaf that was first subjected to an 8°F. difference is now subjected to a 2°F. difference, and of course those ends which showed a 5°F. will remain at this value, and so we are able to show an average hygrometrical difference of 5°F. throughout two half lofts, instead of a drop of from 8°F. to 5°F. in one half loft. Practical tests made in a Badulla factory during very misty weather, when no natural withering at all was obtainable, show that it was possible to obtain withers which varied only 0·9 per cent. from end to end of any two half lofts.

To make these tests, which were carried out by the estate superintendent, leaf was carefully weighed before spreading on the end tats, and again weighed on completion of the wither, and it was found that 50 per cent. more withering was done in the same time by using the reversible system than was obtained when using the other half of the factory lofts, which were equipped with the non-reversing boosting system.

A fifth method of withering is provided in the Research Factory, whereby artificial heat is excluded from the system altogether. This system is intended for use, whenever the outside atmosphere shows a hygrometrical difference of say 5°F. but is still and stagnant. Under these conditions the fan system will provide the necessary movement of air in the lofts, which is lacking during such weather.

It is hoped that the withering equipment provided will enable much useful research work to be done in the first process of practical teamaking, and that before long it will be possible to indicate what degree of wither is the best all round percentage; a point which has never yet been determined.

Another point which requires investigation is the treatment of sopping wet leaf.

I have weighed wet leaf from the field, and found as much as 14 per cent. of the total weight was due to surface moisture.

Now it is usual in most factories to make a deduction for surface water when taking over leaf from the pluckers, but as a rule no such deduction is made when calculating withering percentages. If, therefore, very wet leaf is withered down to a gross 55 per cent. wither, the actual net wither may be as light as 63·9 per cent. and yet it will be logged as 55 per cent.

It would appear therefore, that if any close standardisation of withering percentages is to be aimed at, very wet leaf should be withered down to 48 per cent. to secure a concentration of the juices in the leaf, equal to that obtained by a 55 per cent. wither on dry days when the leaf had no surface water.

A rough and ready rule is to wither wet leaf to 50 per cent. and dry leaf to 55 per cent. and these percentages are found to give fairly similar results under the respective conditions.

There is no doubt whatever that research work in manufacture carried out under expert scientific observation will be extremely helpful to the industry, and there are doubtless just as many problems to be solved in the subsequent processes of tea manufacture, as there are in withering.

In conclusion, I would like to explain why on the Tea Research Factory plan no engine room is shown.

Because all the machinery is driven electrically, there is no necessity for an engine room being built to form part of the factory building. A power house for providing electric current for power and lighting is to be placed some little distance from the factory, for the sake of procuring a good supply of cooling water, and to ensure that no fumes from the oil engines will enter the lofts.

SOME PROBLEMS OF TEA MANUFACTURE.

By

D. I. EVANS.

If the present methods of tea manufacture are compared with those employed when the leaf was rolled by hand, it will be realised that great progress has been made in the art of teamaking. The first attempts to utilise machinery in the manufacture were crude, but enterprise and perseverance have evolved and placed at your disposal machinery which has proved satisfactory and enables you to deal with large crops with comparative ease. While some of the problems with which we are now faced have persisted from the old days, the introduction of machinery and the need to handle big crops have brought in new problems.

Although tea manufacture may be said to begin with the plucking operation, it will be realised that all cultivation and manuring should be carried out so as to produce a suitable leaf for manufacture. As we are dealing with a plant whose activities and life processes depend among other things on the soil it grows in, and also on the light, temperature and humidity conditions it is subjected to, so do we meet with teas of different qualities from district to district, and subject also to seasonal and other variations.

The withering process by means of which the leaf loses moisture and becomes flaccid and suitable for rolling is undoubtedly one of the most important processes in tea manufacture, but diverse opinions are held as to its proper conduct. It is necessary to drive off some of the moisture in the leaf to reduce its turgidity, and thus make the leaf suitable for rolling, so that it takes a nice twist and no loss of juice occurs when pressure is applied. It is contended, however, that the withering process involves a certain chemical change which is necessary for teamaking, and in support of this we have the results of experience which indicate that the best wither is generally obtained when the proper loss of moisture is obtained in 18 to 20 hours. On the other hand claims are made that fine teas have been made when the proper physical wither is obtained in a much shorter period and similar claims are made for a considerable longer period. The conception that the leaf undergoes some chemical change on the tats which renders it suitable for teamaking received further confirmation from the work of Mann who published the results of his investigation in 1901-1903. He concluded that, "During withering, the amount of oxidising enzymes or ferment in the tea leaf increases up to a certain point corresponding under normal withering conditions with the point at which the leaf is ready for rolling."

Mann's work has been repeated in Java by Welter and Bernard (Mededeelingen van het Proefstation voor Thee Nos. 12 and 13, 1911) but, unfortunately, they were not able to verify his results.

It is generally accepted, however, that leaf withered in a very short time results in different tea from that which has been prepared from leaf withered for a longer period, and this is attributed to the fact that chemical wither has not had time to develop in the shorter period used for withering. It would be a decided advantage if some simple test which would indicate the proper degree of the so-called chemical wither could be developed, and recently it has been claimed by Mr. P. H. Carpenter that he has found such a test. I have carried out this test over and over again, but regret to say that it does not lead to any conclusive results.

Dr. J. J. B. Deuss who has investigated the withering process in Java, while not excluding the possibility of a chemical process, points out that there is no proof so far that such a chemical change takes place, and he is inclined to think that the loss of moisture is the only change.

Apart from the loss of turgidity in the leaf during the wither, there is also a concentration effect on the leaf juices as the water evaporates, and Deuss contends that withering should be carried out in such a way as to produce a definite ratio between the solids and the moisture in the withered leaf, i.e., leaf going to the rollers should be withered so as to contain the same amount of moisture each day, and in this way the conditions for the fermentative changes will be the same, the juice pressed on to the surface of the leaf will always have the same concentration. If the amount of moisture associated with the leaf was constant, this could be attained by withering to a constant loss of weight. Unfortunately, the amount of moisture in the fresh leaf is subject to great variations, and withering to 55 per cent. of the weight of the fresh leaf would give one result for leaf associated with high moisture and another result for leaf associated with low moisture. Suppose the fresh leaf has a dry weight of 18 per cent. and this is withered down to 55 per cent. The withered leaf will now contain 33 per cent. dry matter. If the fresh leaf contains 25 per cent. of dry matter, then a wither of 55 per cent. gives a leaf which contains 37 per cent. dry matter, and the ratio of Solids/Water will be 2·3 and 1·7, respectively, and it is likely that the reactions which proceed during fermentation would proceed differently owing to the difference in the concentration.

In order to wither to the same concentration, it is necessary to know the moisture content of the fresh leaf, and this can be easily done by taking samples of leaf when it is spread on the tats, and drying a known weight of it in an oven. The loss of weight necessary in order to produce a certain ratio of Solids/Water could then be calculated. The degree of wither obtained each day can also be checked by this means, if samples of leaf going to the rollers are taken and placed in a covered tin. The weight of the moist tea could then be determined when convenient, and on drying this leaf the difference in weight

would give the weight of moisture in the withered leaf. If samples are taken at random over the tats, a further check on the evenness of the wither and the efficiency of the ventilation is obtained, and when these observations are made in conjunction with observations of time, temperature and humidity, it would be possible to check whether any difference in the tea could be due to the wither. There would thus be available a record of the most important factors concerned in withering, and it would be possible to determine the most suitable wither for working purposes.

Since the composition of the leaf varies, it is possible that it may be necessary to vary the degree of wither to a slight extent in order to meet the new conditions, and such data should eventually help in predicting the change necessary.

Having decided on the amount of moisture to be driven off during withering, it is yet necessary to consider the conditions which determine this loss. The rate at which a leaf will lose moisture depends on the temperature, humidity of the surrounding atmosphere, the velocity with which the air moves over the leaf as well as on the internal condition of the leaf itself, that is, its osmotic and stomatal activity. Evaporation of water from a leaf is not the same as evaporation of water from a free surface, but it proceeds mainly through the stomata or mouth-like openings found on the surface of the leaf. Since the under surface of the leaf contains most stomata. evaporation of water is more active when the under surface is exposed freely to the drying agent, and loss of moisture will thus be facilitated by turning over the leaf during the wither, so that both surfaces of the leaf are exposed to the air current during a part of the withering period.

Although it is the stomata that allow most evaporation from the leaf, a certain amount is undoubtedly lost through the epidermis, and if very dry air is used, the desiccating effect may be so strong as to result in a drying out of the epidermal cells, resulting in a dry brittle leaf instead of the supple product required. This is generally accompanied by discoloration of the leaf and a loss of soluble matter in the leaf itself. Deuss found that the use of air which is too dry results in a drying out of the youngest leaves, thus preventing any fermentative changes in the roller. The soluble material of the leaf thus dried falls from 50 per cent. to 16 per cent., so that a good deal of the soluble material is no longer available for fermentation. A high temperature during the withering process has the same effect on the soluble material.

The external factors governing the rate of evaporation are temperature, humidity and the velocity with which the air moves across the lofts, and withering is simple when the outside air is not too humid. The temperature and the humidity of the air should be determined by means of precision instruments, and when the outside air is

too humid to effect the necessary drying in the time, conditioned air should be used under controlled conditions. The usual method of conditioning the air for tea factories is to use either the hot air obtained from the drying machine during the drying of tea or else the hot air obtained from a separate drier. It is thus possible to mix this air with the outside air and reduce the humidity of the mixture without any big increase in temperature. Care should be taken to ensure that the warm air is properly mixed with the cold, damp, outside air, otherwise uneven drying of the leaf on the tats will occur when the air is drawn over the leaf. When an atmosphere possessing the requisite degree of humidity is obtained, it is necessary to move this air evenly over the leaf on the tats in order to produce uniform conditions throughout the lofts, and the superintendent is faced with the usual problems confronting the ventilating engineer. These are questions of how to admit the air into the lofts so as to produce the most even distribution of air throughout the loft and also obtain the greatest fan efficiency. The methods which will be available for producing artificial withers in the Tea Research Factory have been described by Mr. Whitehead. It will thus be possible to compare one system with the other, and also to evolve a scheme whereby the efficiency of any other system may be tested.

It may be pointed out in passing that the humidity of the air may be diminished by mixing the moist air with cold dry air. Air submitted to a freezing temperature deposits its moisture as dew. A cool dry air can be obtained by passing air over an absorbent-like Silica Gel, a process recently introduced at home with success to dry the air used for blast furnaces. These methods would require special apparatus, and it is doubtful whether they could ever compete with the present system of utilising the waste heat of the driers when this is properly controlled.

Associated with the loss of moisture from the leaf we find a loss of the actual dry matter of the leaf. This was first pointed out by Mann, but the importance of the loss of this dry matter has been overlooked. It must be remembered that a tea leaf is still living when taken off the bush, and requires oxygen from the air in order to carry out its respiratory activity. That is, a tea leaf breathes just as we do; it takes in oxygen from the air and breathes out carbon dioxide with the liberation of heat energy which is normally dissipated into the air. If free loss of this heat is prevented as occasionally happens when the leaf is carelessly packed, then an appreciable local development of heat may take place with deleterious effect on the leaf which becomes discoloured and unsuitable for teamaking. The heat effect injures the protoplasm of the leaf and starts certain chemical changes which resemble those that take place when the tissue is crushed in the rollers. Crushing of the leaf also appears to disorganise the protoplasmic tissue and sets in motion certain chemical changes which cause

a loss of the soluble material of the leaf. The leaf should be treated with care so as to avoid as much damage as possible. Although the elimination of all injury is impossible under estate conditions, it can be minimised by attenton to such details as the proper filling of coir bags. The development of any sensible heat can be prevented but the respiration proceeds, and when this fresh young leaf is spread out on the tats to wither the result is something similar to a crowded theatre full of respiring people, and the air soon becomes heavy (fuggy) unless a proper circulation of the air is maintained. This condition is never met with when a natural wither is possible, but when artificial conditions are employed air movements depend entirely on the fans, and unless these are efficient the air becomes heavy with the accumulation of the products of respiration and the evaporation of moisture. The respiration diminishes during the wither so that the most actively respiring material is the fresh leaf immediately on spreading. When hot air is used for driving off surface moisture, it is usual to open the windows after a while to let in fresh air, which is in keeping with the idea that an accumulation of the products of respiration has taken place. It is, therefore, necessary that any system used for artificial withering should be capable of removing this vitiated air as well as the moisture.

Withering thus presents a series of problems, many of which can be overcome by proper attention to details and greater supervision during the process, but many problems still remain and will remain obscure until we have more light on the question of the so-called chemical wither and the variation met with in the raw material which comes into the factory for teamaking.

When the leaf which has been properly withered is rolled, it is bruised, and the contents of the leaf cells are mixed and exposed to the action of the air, and the so-called process of fermentation commences. The greatest problem of tea fermentation is to obtain a clear knowledge of what causes the chemical transformations involved in the production of black tea. A comprehension of these processes is hindered by the lack of any chemical criterion of the quality of tea, and the meagre knowledge of the chemistry of tannin which plays such an important role in the production of colour and the pungency of a tea infusion. While good tea may be produced and improvements effected by empirical methods, complete control of the fermentation process will never be obtained until we have a clear knowledge of those chemical changes.

Several theories have been submitted to explain the fermentation of tea.

(a) *Chemical Theory*.—This regards fermentation as a simple oxidation of the juices when exposed to the air. It fails to explain why leaf killed by steam will not ferment.

(b) *Micro-organism Theory*.—This was first suggested by Kozai in 1891 (Researches on the manufacture of various kinds of tea, Tokyo, 1891), and in 1903 was again brought forward by Wahgel (Uber Thee Gabrung Chem. Zeit. 1903) in connection with the production of flavour. Bernard in Java isolated several organisms associated with the leaf, and claimed that certain yeast-like organisms increased rapidly during the wither, and were responsible for the actions concerned. Later work in Java has resulted in a withdrawal from this point of view in favour of the enzyme theory.

(c) *The Enzyme Theory*.—The tea leaf contains an enzyme system which accelerates the oxidation of tannin bodies with the formation of red to brown coloured compounds and these give an infusion of tea its characteristic colour and properties.

The last theory seems to fit in best with our present knowledge of teamaking, but there is no doubt that the chemical change involved is a complex process which is accompanied by a decrease in the water soluble material of the leaf, most of which is represented by a loss of tannin. It has been shown by Deuss that the tannin present in tea can be oxidised with the formation of red to brown products whose solubility in water varies. He suggests that during tea fermentation the tannin is oxidised with the formation of these products which are responsible for the colour and the strength of the liquors. If the fermentation is carried too far, then too much of the tannin passes into the insoluble form, and the liquors in spite of their good colour will be thin. Humid conditions favour the formation of these red coloured compounds, and at present every effort is made to maintain the rolling and fermenting room as moist as possible . In this connection it may be pointed out that the modern idea of placing a factory in such a position as to get the greatest movement of air for withering purposes has added to the difficulty of maintaining the rolling room moist, and has made necessary the use of mechanical devices for creating the necessary humidity.

The problem of tea fermentation is therefore how to control the changes which take place in these tannin bodies, and it will be necessary to determine the relation between different ways of rolling and the properties of the made tea, as well as the effect of temperature, humidity and time of fermentation on the end product. Although I have stressed the importance of obtaining a clear conception of the chemical changes, it is still possible to determine some of the relations which exist between the process of rolling and fermenting and the character of the made tea by empirical methods, without waiting until the chemistry of tea is elucidated.

It would take too long to discuss all the problems associated with tea fermentation, and subsequent treatments during drying and sorting, but I would like to mention one other problem of tea manu-

facture which it is hoped will prove of interest and that is the possibility of the introduction of mechanical means to handle the tea leaf. There is no reason why transport bands should not be used to carry the leaf not only up to the withering lofts but even to the tats, and from the roller into the roll breakers, and from the fermenting tables to the driers, and so on.

Such mechanical innovations are being experimented with in Java, and would prove of great value if such a scheme could be devised.

The last word has not been said about driers and sorting machines, and it is quite possible that better drying could be accomplished by means of rotary drying machines as used for drying such sensitive materials as milk sugar, fine quality coffee, etc. Dr. J. J. B. Deuss of the Java Tea Experimental Station has recently described new machines for grading tea working on the principle of the winnowing machine, and which effect a considerable saving of time, labour and machinery, while the appearance of the tea is improved.

DISCUSSION.

Mr. D. J. Malcomson asked Mr. Whitehead whether his experiments on humidifying the rolling room had been carried out at high or low elevations. He said it was generally known that when two atmospheres were compressed into one, the heat of the resultant mixture was doubled, so that if air was pumped by fan or otherwise into the mist chamber the pressure developed would result in a rise of temperature unless some cooling arrangement was installed. It seemed to him that on a low-country estate where the outside temperatures were high, it would be very difficult to obtain the necessary humidity without increasing the temperature of the rolling room if the air was forced in under pressure. He suggested that it might be better to experiment on drawing air from outside into the rolling room, and humidifying it in some way without increasing the pressure.

Mr. Whitehead replied that the problem was how to reduce the temperature of the air to that of the wet bulb. His experiments had been carried out in the Badulla district at an elevation of 3,500 feet, where the temperatures were as high as 90° Fahr., and the hygrometric differences were as much as 22° Fahr. The success of humidification depended on the initial temperature of the air being high when compared with the wet bulb temperature. If the dry bulb temperature was 95° Fahr., and that of the wet bulb 93° Fahr., further humidification would be very difficult, but if a dry bulb temperature of 95° Fahr., was associated with a wet bulb temperature of 75° Fahr., then this air could be humidified because it had much heat available for the evaporation of water. The humidity of the air was increased by the evaporation of water, and as the air travelled 40 feet through a fine spray in the mist chamber, it had sufficient time to absorb the fine particles of water it came in contact with, and to become saturated with moisture before it reached the rolling room. Mr. Whitehead pointed out that there was no danger of heating by forcing the air under pressure into the rolling room because the increase of pressure was only equal to 1/16 inch water gauge. The compression was therefore very slight and any heating effect due to this would be negligible.

Mr. Malcomson said that he agreed with the principle stated by Mr. Whitehead, and that he had found it possible to reduce the inside temperature by 6° Fahr., by drawing the outside air through wet hessian or other coarse fabric.

Mr. Whitehead replied that he had carried out experiments by blowing air through wet cloths and then determining the humidity of the air after passing through the cloth. The results obtained proved that this method of humidification was inefficient, since passage of air through a single layer did not produce good saturation. In order to obtain saturated air, it was necessary to interpose several layers of cloth, but when sufficient wet cloths to saturate the air were used, they offered so much resistance to the passage of air as to make proper ventilation impossible. It was possible, when starting with a dry bulb temperature of 90° Fahr., and wet bulb temperature of 80° Fahr., to humidify the air in such a way as to obtain a dry bulb temperature of 80° Fahr. In his tests he had been able to humidify the air so as to diminish the dry bulb temperature by about 12° or 13° Fahr., in a very short time.

Mr. J. Horsfall suggested that a definition of a natural wither was that of the circulation of fresh air of a given degree of dryness. When the outside atmosphere was too humid, a wither could be obtained by using air tempered in such a way as to show a hygrometric difference of about 8° Fahr. Although the systems suggested by Mr. Whitehead for carrying this out might appear complicated they were really very simple, and it was very easy to teach the loft cooly how to read his hygrometer and to control his air mixture to give a certain hygrometric difference. It was pointed out in Dr. Evans' Paper that the leaf required oxygen during the wither and that it was necessary to supply the leaf with sufficient fresh air, not with vitiated air as was done under some of the older systems. He asked Dr. Evans whether the variations in moisture content he had referred to in his paper were a result of climatic conditions or of the age of the bush from pruning.

Dr. Evans replied that the moisture content of the leaf itself varied, but that it was very difficult to differentiate between the moisture within the leaf itself and that found on the surface of the leaf. The total moisture associated with the leaf was referred to in the paper since this is the factor which decides the work required to wither the leaf. Although the moisture content of the leaf varied according to the climatic conditions and period from pruning, this variation was very small when compared with that due to changes in the surface moisture resulting from climatic conditions at the time of plucking. It had been found that on wet days the moisture associated with the fresh leaf can be three times as much as can be found with fresh leaf in dry weather.

Mr. A. Bruce asked Mr. Whitehead if he had used recording hygrometers in his investigations in factories.

Mr. Whitehead replied that these had been used but that their general use was not practicable, owing to the fact that they were easily put out of action and misused by the loft cooly, whereas wet and dry bulb thermometers were simple and quite efficient for working purposes.

Mr. E. E. Megget said that he had observed a difference between fresh leaf obtained in wet weather and that obtained in dry weather. It was his experience that wet weather leaf was more turgid and was apt to putrefy more readily than the dry weather leaf. He would like to know whether this was due to a difference in the moisture content of the leaf or to some difference in the composition of the leaf,

Dr. Evans replied that wet weather leaf would have a higher moisture content than dry weather leaf, and this would tend to make the leaf more turgid and liable to damage, but he could not say whether this would render the leaf more liable to putrefaction or not. It must be remembered that the greater amount of moisture associated with the wet weather leaf involved more work during the withering process if wet leaf was to be withered to the same degree as dry leaf. The evaporation of the moisture was not so easily done under such climatic conditions, and there was a tendency to lengthen the wither and to use warmed air for withering, which would partly account for the tendency to putrefy. There was no doubt that certain chemical changes of the nature of putrefaction were going on during the wither but the extent to which these changes would proceed would depend on the temperature, time taken to wither and also on the composition of the leaf. The variation in the composition of the leaf was being investigated, but it was not yet possible to state what they were.

Mr. H. A. Webb asked what constituted good tea and how could good tea be judged as it was not possible to do this from the market valuations.

Dr. Evans agreed that there was no one criterion of good tea and Mr. Webb had touched upon a problem which he had met at the outset of his investigation. There was no chemical criterion of quality, and if any definition of good tea could be given, then the investigation of the factors governing quality would be simplified.

Dr. C. H. Gadd said that what underlay many of the problems of manufacture was a very imperfect knowledge of the chemistry of tea, and any improvement of that knowledge would elucidate many of the problems. Little was known of the chemical composition of the leaf as it came into the factory, and no more was known of the constituents of the made tea sent to market. Attempts were made to turn out a product with the elusive quality termed flavour, but what substances stimulate the palate and so give rise to the particularly desired sensation, i.e., flavour was not known. A knowledge of these chemical matters and of the changes which took place in each process of manufacture would assist the solution of the problems confronting the teamaker.

Both Mr. Whitehead and Dr. Evans had referred to the problems of withering. One had referred to it as an engineering problem of devising machinery for obtaining uniform or even wither in a desired time. The other saw the withering leaf as a living object, carrying on certain life processes which resulted in chemical changes having possible important effects on the quality of the tea which resulted. These two standpoints indicated the policy which the Institute must adopt. Research in the factory must accompany investigation in the laboratory. It was useless, as Dr. Evans had said, to wait for our knowledge of the chemistry of tea to advance sufficiently to elucidate the problems. That the manufacture of tea had been advanced to its present position was due mainly to empirical methods of research. These methods had proved very successful and had justified their continuance by the Tea Research Institute.

They were fortunate in having a man with the knowledge and experience of Mr. Whitehead to design the Institute's factory. He (Mr. Whitehead) had done a good deal of experimental work in tea manufacture and realised the importance of 'controlled conditions' in experimental work. Controlled conditions, as the term was understood by scientists, were impossible to attain in any tea factory, but, he thought, Mr. Whitehead had supplied everything possible. The facilities provided for the research officers were such, that, in his opinion, the Institute would be able to help the planter to improve his methods of manufacture.

Mr. J. P. Blackmore asked Dr. Evans whether he could say at what stage of the rolling process the most pronounced flavour was obtained, when did the flavour begin to be lost, how many rollings and what amount of pressure he would advise in order to obtain the best quality.

Dr. Evans replied that the points mentioned were problems they hoped to investigate as soon as the factory was established. He believed that the question of rolling and the pressure at the time of rolling depended very largely on the type of tea one sought to produce.

Mr. Blackmore asked how many samples had been tested by tasters in Colombo.

The Chairman, in reply, said that they had sent down two invoices of tea manufactured from leaf grown on the Tea Research Institute's estate. This had been manufactured by an outside factory, but it was very difficult to go into the problems referred to by Mr. Blackmore until they had their own factory and had the manufacture controlled by their own superintendent. He suggested that questions of this nature should be left over for a subsequent conference when the results of work carried out on these lines would enable them to answer these questions.

Mr. P. G. Boileau asked whether light had any chemical effect on leaf that was fermenting.

Dr. Evans replied that he had no information on that point, but that an investigation of this problem had been carried out in India. The results of that investigation did not show that there was any connection between the light, i.e., its colour and intensity, and the fermentation process, provided direct sunlight or glare was avoided.

THE RELATIONSHIP BETWEEN FOOD RESERVES OF THE TEA BUSH AND DISEASE.

By

C. H. GADD.

Since the beginning of civilisation, the tiller of the soil has been robbed of some of the fruits of his labours by plant diseases. The part played by parasites, fungi in particular, in the causation of these diseases has been recognised only during the last century. Fungi were regarded as mere creatures of putrescence, and therefore as the consequence, not the cause of disease. The brilliant work of Berkeley and other mycologists about the middle of the last century dispelled that idea, and now it is conceded on all sides that many plant diseases are caused primarily by fungi. There is therefore an intimate connection between mycology (the science of fungi) and plant pathology. The relationship is so close that in other countries besides Ceylon, plant pathologists are often termed mycologists. I do not wish to criticise that terminology as I have nothing better to substitute, but I would suggest that a plant pathologist, to be worthy of his profession, must be something more than a pure mycologist.

A parasite, if present, is of course part of the plant's environment in its widest sense. But, if we separate the parasite from the general environment, we have three factors which play important though variable parts in the causation of disease, viz. parasite, host and environment. For many years emphasis has been laid mainly on the parasite, which partly accounts for the fact that most plant diseases are known by the name of the fungus which has been proved, or is supposed, to cause the disease, e.g., Cercosporella, Poria, Ustulina. The use of the fungus name as a label for a diseased condition has its advantages; it also has disadvantages to which I will refer later.

That the physical, chemical, climatic and other factors which comprise the general environment are often of paramount importance in the inception and spread of disease, is well known to planters and scientists alike. Very rarely indeed is a disease caused solely by the bringing together of host and parasite. Environmental conditions must be suitable; if they favour the parasite, disease is likely to result, but not otherwise. In some cases the factors of a plant's environment, apart altogether from the presence of any parasite, has a profound effect on the plant, and may be the primary and sole cause of disease. Apart from such obvious conditions as drought, lightning and waterlogging, I would mention a single example, namely 'Leaf Scorch' of fruit trees which recent research has demonstrated to be a result of a deficiency of potash.

The third factor to be considered is the host or the plant itself. This in the past has been the most neglected side of the eternal triangle of plant pathology. Plant pathologists will admit that often they know too little about their patients, how they grow and what conditions favour their growth. This deficiency is gradually being remedied and the knowledge obtained will certainly be of great benefit to plant pathologists in their study of diseases.

So long as there are three sides to plant disease problems, viz., parasite, environment and host, there will always be three angles of approach to those problems. As mycology is one of the foundation stones of plant pathology, and the real founders of serious study of disease in plants were mycologists, it is not surprising that most diseases are first approached from the angle of a possible parasite. One of the first things a plant pathologist does when investigating an unknown disease is to list the parasites found in association with it. This, however, does not close the other angles of approach. Obviously, if a particular disease is not caused by a parasite, research from the parasite angle is likely to prove abortive.

Criticism has been levelled at the work of the Tea Research Institute in that "Efforts are being made to treat failure to recover from pruning as a so-called physiological disease before the possibilities of parasitism on the part of a consistently present fungus are exhausted or even considered, a step that is indefensible when there is evidence of the presence and for the parasitism of the fungus in question." (T. A. Vol. LXXI, p. 226.). Obviously, a mycologist was the critic, but he has taken a stand, which in my opinion, would not be supported by the majority of mycologists today. I have already shown that there are other angles of approach to plant pathological problems than the mycological, and no apology is required for their use.

The disease in question is that known as the Diplodia disease of tea roots. The name Diplodia is obtained from the fungus *Botryodiplodia Theobromae* which is constantly associated with the diseased condition. Unfortunately, the same fungus is found in association with other distinct diseases, and the name Diplodia has been applied to them all. This has resulted in a certain amount of confusion.

Diplodia was first recorded as a disease of tea in India by Watt and Mann. The fungus was found to attack young tea on grass land when three or four years old. "The leaves of the plant take a yellow appearance, in which the network of the veins is very prominently seen (an appearance easily recognised after a little practice) and then they begin gradually to fall off and branch by branch the bush dies." Tunstall (Ind. Tea Assoc. Bull. No. 1—1918, p. 15) states that this disease is found in all the districts of N. E. India. "It is serious only in two or three gardens in Bishnath and the Dooars on very sandy soil liable to drought. . . . .A plant attacked by this disease shows at

first no indication of disease except in a few cases where the veins of the leaves darken a little in colour. Suddenly, without warning, the bush dies with all its leaves attacked just as though it had been struck by lightning."

In Java, the Diplodia disease has been noticed after very pronounced drought. On one estate 380,000 bushes were dug out within one year, having first been weakened by drought and subsequently attacked by Diplodia (Archief v.d. Theecultuur, June 1928, pp. 59-68).

In Ceylon, the disease commonly known as Diplodia occurs only after pruning, and its occurrence is independent of drought, and is not confined to sandy soils. It is true that deaths of nursery plants and bushes in full leaf adjacent to large-ringed Albizzias have been attributed to the same fungus, Diplodia, but such cases are rare in comparison with the number of deaths which occur after pruning. It is highly probable that we are dealing with more than one disease, judging from the symptoms and mode of occurrence, but because the Diplodia fungus is associated with them all, they are all known as Diplodia disease. This is one of the disadvantages, I mentioned previously, of naming diseases after the fungus associated with them.

The only form of Diplodia disease to be considered here is that which occurs after pruning. Of this form of Diplodia disease, Petch (Diseases of the Tea Bush, p. 151) wrote: "If untreated, the number of bushes attacked increases with each successive pruning. At first, perhaps only a few bushes die and little notice is taken of it; at the next pruning, the number is greater and attracts some attention; and the increase continues with each pruning until 50 per cent. of the bushes may be attacked. Four prunings may convert the indifference into panic." Between prunings the bushes show no sign of disease; they flush well as a rule, but when pruned a large number fail to recover. The affected bushes do not occur in a group, they are scattered haphazard through the pruned fields and in that respect the incidence of the disease differs from the majority of tropical parasitic root diseases.

It is evident that this form of disease is closely connected with the operation of pruning, otherwise why should the disease occur in a severe form only after pruning? At the same time it is evident that pruning itself is not the cause, otherwise why does not the disease occur in all pruned fields? There must be some other factor at work which is operative only after pruning.

The fungus, *Botryodiplodia Theobromae*, in short Diplodia, is known as a parasite of cacao, sugar-cane, and Hevea, but it is generally regarded as a weak parasite, i.e., it can gain entrance through wounds and may attack plants of low vitality. If the vitality of the tea bush is low after pruning, it appears possible that Diplodia will attack it and so cause the disease. That possibility has been regarded

as the real explanation of the occurrence of the disease. But, it raises the question: "Does pruning materially lower the vitality of a tea bush ? That question cannot at present be answered with a definite Yes or No. If the answer is Yes, some explanation is required of the apparent immunity of some fields from the Diplodia disease after pruning, as the fungus is one of the commonest in the tropics and occurs throughout the tea districts; consequently, all pruned tea would be liable to attack. We should also have to regard the pruning operation as the primary cause of the disease in so much as the cutting of the stems lowered the vitality of the bush and so made the disease possible. The evidence is entirely against this view. If the answer is No, then the explanation fails.

It is impossible to avoid the fact that if deaths after pruning are not the direct result of pruning, they are the result of the operation of some factor which becomes dominant at pruning time. If that factor is not a weak parasitic fungus, what is it ?

The discoveries by the Tea Research Institute that the tea bush stores its reserve food supplies within its root system, and that bushes which fail to recover after pruning are destitute of such reserve foods provide a satisfactory explanation of the problem. It is not the pruning itself which causes the death; it is pruning at a time when the bush has not the food material with which to build up new parts to replace those removed by the pruning. The vital parts in question are the leaves. An account of this view of the causation of the so-called Diplodia disease has already been published. (T. Q. Vol. I, pp. 89-93, 1928) and it is unnecessary to cover the same ground again here.

In order to understand this view, we must abandon the idea that manure mixtures constitute the true food of the bush. They are only raw materials which the bush transforms into part of its real food. The true foods are manufactured from raw materials obtained from the soil and the air, and this process of elaboration takes place in the leaves. Without leaves, the bush cannot use the raw materials and consequently is dependent upon the food reserves it may have stored within its tissues for further growth. If, when pruned, the bush has no reserve food, it can make no new growth; consequently, it cannot recover from pruning and so must die. When dying or dead, the tissues become invaded by fungi, and it is to be expected that the commonest fungi will be found most frequently in the dead tissues. Hence, the constant presence of the Diplodia fungus.

We have therefore two demonstrable facts to consider and to ascribe to them their correct value in causing the disease. (1) The dead bushes have common fungi such Diplodia in their tissues, and (2) the bushes are deficient of reserve food material. It has been suggested (T. A. LXXI, p. 226) that the latter condition is a direct result of the former, i.e., the presence of the fungus has resulted in the depletion of the food reserves. That is a point worthy of consideration. If the fungus uses the starch within the tea root for its

own purposes and so causes the death of the bush, then the fungus must be regarded as the primary cause of the disease.

If the fungus devours the starch it cannot run way after its meal. It must be present within the tissues in sufficient quantity to account for the complete removal of the food material. A healthy tea root is filled with starch as may be seen from the photographs (published in the T. Q. Vol. I, plate IX) whereas the corresponding tissues of the diseased root is destitute not only of starch but also fungi. The fungi present in the diseased roots are in the cortex only (at least in the early stages) whereas the starch is within the wood.

To elucidate this point, examinations have been made of the roots of bushes which had failed to make any new growth within normal time from pruning, i.e., by the time the majority of the bushes in the field were almost ready for tipping. Many of these roots were alive and not attacked by fungi, but in every case there was an absence of starch. This absence cannot be attributed to fungus attack in those roots which bore no fungus. In some cases, the whole root system of the bush was free of fungi; yet starch was everywhere deficient.

These observations not only refute the suggestion that the depletion of starch is the result of fungus activity, but lend support to the hypothesis that the delayed recovery from pruning is a direct result of the deficiency of the food reserves.

Lastly, I would mention that as far as I have been able to ascertain, the deficiency of food reserve is characteristic only of Diplodia disease associated with failure to recover from pruning. The roots of bushes killed by Poria, Rosellinia, and Ustulina usually contain starch in quantity. If, as our critic claims, these diseases are caused not by the fungi from which they are named, but by a species of Rhizoctonia, then his suggestion that the shortage of food reserves in the so-called Diplodia disease "is caused directly by Rhizoctonia attack and advance" must fall. He cannot have it both ways. If the advance of Rhizoctonia preliminary to the entry of and in conjunction with Poria fails to remove the starch, its advance in the absence of Poria will certainly not remove all traces of that food material from the tissues. In any case the advance of Rhizoctonia through the starch depleted tissues has not been observed.

I have dealt with this point at some length because of its importance, and because I am convinced that the deficiency of food reserves is the primary cause of the failure of tea bushes to recover from pruning. This hypothesis is not pure conjecture; it is founded on numerous observations, both qualitative and quantitative, and is worthy of careful consideration. The fungi found in the diseased bushes may or may not assist in the final stages of the killing, but economically they are unimportant. If the disease is to be prevented, we must avoid the depletion of the food reserves; treatment directed towards the control of unimportant soil fungi must prove ineffective.

The rate at which a food reserve is built up or depleted will depend on two things: (1) the rate at which the food can be made; and (2) the rate at which it is used up. If (1) is greater than (2), a reserve will be formed; but if (2) exceeds (1), the reserve will be depleted.

It is highly probable that all tea bushes are not equally efficient in utilising the energy of the sun to transform the raw materials into elaborated food. Climatic and environmental conditions generally will also affect the rate of food formation, but this process has not been closely studied in the tea bush. It is certain, however, that the leaf is the organ in which the main process takes place. In removing the young leaf as crop, we take away organs which in the ordinary course of things would normally become places for the manufacture of more foods.

The food as it is made is used to support the vital life processes and for the construction of new tissues. Growth, whether it is measured as elongation or thickness, demands large supplies of food. The new shoots, collected as crop, are formed at the expense of food materials. Plucking the young shoots stimulates further growth which calls upon further food supplies. It follows that where the rate of manufacture is constant, the bushes which make the greatest growth will have the least opportunity of storing reserves. It is a significant fact that Diplodia occurs with greatest severity in those districts in which growth is most rapid, i.e., where the plucking rounds occur most frequently.

That climatic conditions have a marked effect on growth rate cannot be doubted. It is possible that conditions which favour growth also increase the rate of photosynthesis (the making of food materials), but on this point our knowledge is not very exact as regards the tea bush. From field experience it appears very doubtful that the increased rate of food manufacture is commensurate with the increased rate of consumption resulting from the extra growth.

Then comes the time when the bush has to be cut back. With normal pruning the bush is denuded of leaves and all new growth must be built from the food reserves. This is a critical period in that a food reserve is absolutely essential; without it, no further growth can occur. The type of recovery will depend to a large extent upon the amount of reserve food. If sufficient, the recovery will be complete; if insufficient, a few new shoots only will be formed. Such partial recoveries are well known in most Diplodia fields.

Growth after pruning depletes to some extent the stock of reserve foods, and unless this loss is made good during the next plucking cycle, the bush will have a smaller reserve to draw upon when next pruned. This continuous depletion may go on until the time comes when the bush has insufficient reserve for its needs at pruning time. This affords an explanation of the increased losses at successive prunings already referred to.

The more frequently a bush is pruned, the more often is a call made upon its reserve food. It is therefore not surprising that the disease occurs with greatest frequency where the bushes are pruned most often. Unfortunately, the fields which are plucked most frequently are also those which have to be pruned at short intervals.

In these two circumstances we have two factors which tend to prevent the accumulation of ample reserves. At higher elevations, where growth is less rapid and where the plucking rounds are of necessity less frequent and the pruning cycle runs to three years, the so-called Diplodia disease after pruning is almost unknown.

The factors which lead to the depletion of food reserves in the tea bush are complex and not completely understood, but this depletion can cause the death of bushes after pruning as surely as the attack of any virulent parasite. If such losses are to be prevented methods of cultivation must be adopted which will allow the bush to build up essential reserves. The deficiency cannot be remedied by artificial means; the bush has to do it itself, though conditions may be made as favourable as possible for it. The problem is not solely a manurial problem, though no doubt, when we know more about the effects of manure on characters other than the cropping capacity of tea, something may be done from this direction.

The more obvious solutions at the moment are rest and light pruning. A rest from the attentions of the plucking cooly before pruning should enable the bush to accumulate a store to meet its needs after pruning. The length of the rest will depend upon circumstances. At present no definite time can be stated, as our knowledge concerning the rate of accumulation of a food supply is very inadequate. Experiments are necessary and are worth trial on fields known to be severely affected.

A light form of pruning which leaves a fair proportion of leaf on the bush is also worth trial. If the bush has leaves, the photosynthetic processes will continue and enable the bush to manufacture at least some of the food it requires. There is then a much smaller call upon the food reserves, and this smaller withdrawal is more likely to be restored before the bush is again pruned.

Much work remains to be done before this problem can be completely solved. If we have now ascertained the true cause of the disease, and the evidence strongly supports that view, we have made a large step forward towards ascertaining the best methods of its prevention. This much, however, is sure: if the economics of tea cultivation are to be placed on a sound basis, some consideration must be given to the internal economics of the bush itself.

DISCUSSION.

Dr. Gadd, in reply to a question, stated that a special study of the effect of soil conditions on the incidence of Diplodia had not been made. The disease had been observed under all sorts of low-country conditions on all types of soils, and there appeared no reason to believe that the disease occurred with greater frequency on one soil type than another. Superintendents had frequently tried all kinds of manure mixtures as cures, but they had never proved successful. No doubt, experiments might have to be devised for ascertaining these points, but at present he could give only general conclusions based on general experience on estates.

Mr. W. A. Perera suggested that a soil bacteriologist should be appointed to the staff.

The Chairman stated that this question had received the careful consideration by the Board. At the present moment, although they thoroughly appreciated the necessity of a soil bacteriologist, they could not proceed with the appointment for several reasons, mainly connected with accommodation and finance. The next officer to be appointed would be a Plant Physiologist, but it was difficult to say when that would be. Owing to the large building programme, the question of enlarging the establishment was one requiring careful consideration, but the Board would keep the point before them and would see what could be done to give effect to the suggestion.

Mr. D. J. Malcomson said that after 30 years' experience on one estate he had come to the conclusion that there was less dieback today than in years past. He attributed this to more liberal cultivation. He agreed with Dr. Gadd that once a bush got dieback after pruning nothing could be done with it, but he felt that there was something in strengthening the constitution of the bush even though it might not actually be a cure for the disease. There was also the question of hard and light pruning. He considered that where bushes were merely cut across, instead of being light pruned, far more dieback resulted.

Dr. Gadd replied that the strengthening of the constitution of the bush to which Mr. Malcomson had referred meant much the same thing as he himself had advocated. If the bush was treated in such a way that it was allowed an opportunity of accumulating a store of reserve food, the bush was strengthened thereby and was enabled to make new growth after pruning. The question of hard or light pruning was usually somewhat contentious amongst planters. His opinion was that light pruning should be adopted in fields known to be affected by the Diplodia disease. The type he had in mind was one which left a fair proportion of leaf on the bush to carry on the work of starch formation. He was pleased to say that a number of experienced planters had arrived at the same conclusion independently of his own work on the subject. At the same time he recognised that such light pruning could not be continued indefinitely and that at intervals a more or less normal prune was necessary. He suggested that a normal prune after about 8 years of light pruning might be adopted.

Mr. A. R. T. Gibbon remarked that Dr. Gadd had given them an interesting line of thought in the search for reasons for excess of mortality in the tea bush after pruning. His theory was that the mortality was largely due to the lack of starch in the tea bush. The question then arose as to what they were to do with the bushes already affected by the disease. Had Dr. Gadd any recommendation as to how the affected bushes should be treated.

Dr. Gadd said that the only thing to be done with a tea bush which failed to recover from pruning i.e., had died of the so-called Diplodia disease was to get it out and burn it. Diplodia fields should be relieved of diseased bushes if trouble

from other diseases was to be avoided. Dead bushes left in the soil were likely to become centres of infection for parasitic diseases. The treatment of the disease was essentially one of prevention.

Mr. C. C. Marsh Smith asked whether Dr. Gadd condemned the orthodox method of pruning and how could a tea bush feed itself when it had no leaves.

Dr. Gadd replied that he did not condemn the orthodox pruning. Normally, tea bushes stored reserves of food materials, mainly starch, within their roots. When pruned so that it was completely denuded of leaves, a bush with a reserve of food used that food to build up new shoots. It fed on its reserves. But, if a bush without a reserve store of food, was denuded of leaves, it could make no further growth because it had neither the necessary food nor the leaves in which to make it. A reserve of starch was absolutely necessary if a bush was to recover from orthodox pruning.

Mr. Marsh Smith then asked how it could be ascertained whether a bush had the necessary starch before pruning was started.

Dr. Gadd said that if a root was removed and iodine applied to the cut surface, the presence of starch in the root would be shown by the change of colour to dark blue or black. A root without starch became yellow where the iodine was applied to the cut surface. He admitted that it was impracticable to test every bush in a field in that way. But when a few deaths occurred after pruning, the planter received a warning that the reserve foods were becoming depleted and he should take steps to remedy this. He should also adopt a lighter form of pruning after this warning and not carry on orthodox, clean pruning until the condition was aggravated and he was losing 25 to 30 per cent. of his bushes.

Mr. Marsh Smith said that the reason he put that question was that he had experimented with a light form of pruning known as the 'lung system'. He found that he had only 13 deaths in that field, whereas in a similar area pruned normally 67 deaths had occurred.

Dr. Gadd said that those figures were of interest and that they supported his own conclusions.

Mr. A. R. T. Gibbon asked whether they were to understand that the resting of bushes before pruning was recommended.

Dr. Gadd replied in the affirmative.

The Chairman said that he could give an illustration of the benefit of resting the bushes from his own experience. A field affected by the Diplodia disease had been rested for 2½ months before pruning and the result had been most gratifying indeed. The field had recovered well and there had been far fewer deaths from the disease.

He had carried out the 'lung system' referred to by Mr. Marsh Smith, and for which Mr. J. Horsfall had been mainly responsible. The same practice had been adopted in mid and low-country estates, and perhaps Major Oldfield had experience of it in Kalutara to record.

The Hon. Mr. J. W. Oldfield said that he had very little to add to what the Chairman had said. He had seen the system in force for nearly three years in the Low-Country and the results were most gratifying. He originally adopted the system on Dr. Gadd's advice, and the results of his experiments in Kalutara and elsewhere in the Low-Country had confirmed everything Dr. Gadd had said.

He expressed the opinion that the Institute had justified its existence up to date by the extremely fine work Dr. Gadd had done on this subject. If the Institute had nothing more to show for the last two or three years' work, Dr. Gadd's paper proved that the work was being conducted along the right lines.

Mr. J. Horsfall endorsed what Mr. Coombe and Major Oldfield had said about the recovery of stricken fields after light pruning.

Mr. P. A. Keiller, referring to the recommendation to rest the bushes before pruning, asked whether any information was available regarding the rate of transportation of starch from the leaf to the roots. This information was of importance because it would have a direct bearing on the length of time bushes should be rested. As regards fertilisers, Dr. Gadd had said that manurial treatment had not proved successful and Mr. Malcomson seemed to have the same idea. Mr. Malcomson, however, had pointed out that well manured bushes did not suffer in the same way as those which had been unmanured. He thought that as the disease had been in existence for a great many years, it was hardly to be expected that one or two rounds of more intensive cultivation were going to put it right. The treatment had to be given time to prove its value.

Dr. Gadd replied that he had found that tea leaves on cut shoots, kept in the dark, completely emptied themselves of starch within three days. The amount of starch which could be transported in a given time had not been determined, but the process was one which went on continuously day and night. As regards manurial cultivation he (Dr. Gadd) had not made himself sufficiently clear. When he stated that manuring was not a cure, he had not intended to imply that the general manuring programmes that were carried on from year to year were valueless in preventing this disease. What he had in mind was the application of particular fertilisers after pruning to those bushes which were slow in making new growth, i.e., to bushes which were affected by this disease. Experience had shown that this method of treatment, the application of manures for this particular purpose, was unsuccessful. He wished to make it clear that he had nothing to say against the manuring of tea. The value of manures in the general cultivation of the tea bush was well known, the practice was well established and stood on its own merits.

Mr. J. C. Haigh said that if the disease was not caused by a fungus, yet it increased from year to year, surely there must be some other contributory condition which was not entirely an inherent weakness of the bush to manufacture enough starch. Such a condition might be one of environment. In the circumstances, resting the bushes must be regarded as a palliative and not a cure.

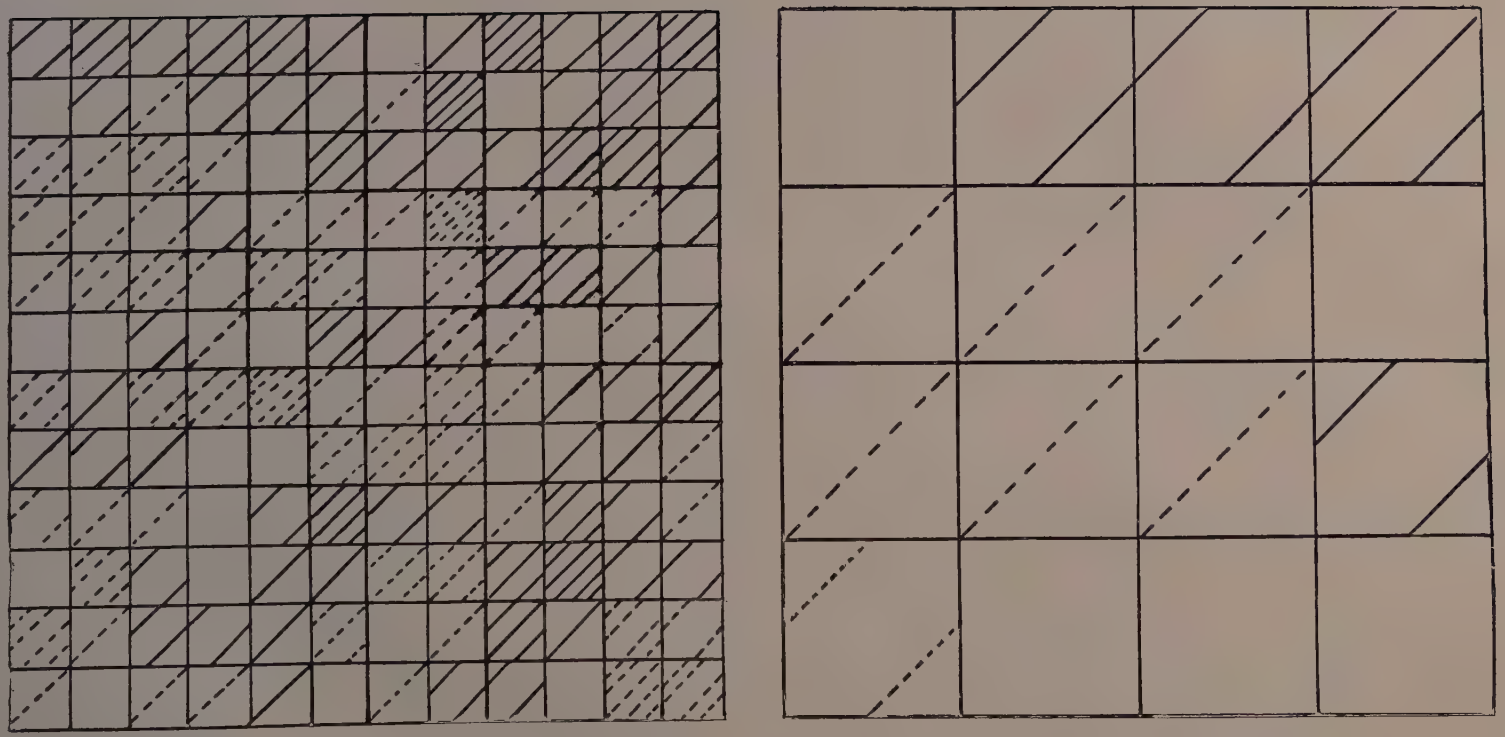
Dr. Gadd said that the main contributory cause was the plucking cooly. Directly the bushes were rested, they had an opportunity of accumulating the food reserves necessary to support the growth after pruning. It appeared immaterial whether the treatment was termed palliative or curative; the result was the same.

Mr. Bruce Gibbon enquired whether excessive mortality after pruning had been reported from estates free of shot-hole borer.

Dr. Gadd replied that when estates submitted diseased bushes for examination they rarely volunteered any information. It was impossible to say therefore if he had ever diagnosed the Diplodia disease from estates free from shot-hole borer. Bushes which made a poor recovery from pruning as a result of severe shot-hole borer attack could be differentiated from Diplodia bushes by the presence of starch in the roots of the former.

Mr. L. Dawson Campbell reminded Dr. Gadd that four or five years ago, after visiting the estate of which he (Mr. Campbell) was in charge, he had recommended lime in the treatment of this disease. Had Dr. Gadd reason to change his opinion regarding the value of lime against this disease.

Dr. Gadd replied that at the time of that visit, the fungus Diplodia was considered to be the real cause of the disease, and lime had been stated to be a corrective. He had himself seen what appeared to be good results following the use of lime, and so recommended its use as he then knew of no better remedy. Since then he had been able to devote considerable time to the study of this disease and had, he believed, now arrived at the true cause of it. He recounted how on one estate lime was regularly applied to backward bushes after pruning with apparently satisfactory results, until one year, for some reason or other, the lime treatment was omitted, yet a similar percentage of recoveries was obtained. Since then lime had not been used because equally good results were being obtained without the lime. This condition could be explained on the starch deficiency theory. The bushes with very little food reserves were late in starting their new growth. Those with just enough to carry them on to the self-supporting stage would survive, but those with insufficient would die back. Where lime had been applied, the recoveries had wrongly been attributed to the effect of the lime, so he no longer advocated the use of lime in the treatment of this disease.



A B

Figure 1. Heterogeneity of Uniformity Trial Plots, (a) individual plots, (b) groups of nine. Each bar of shading represents a deviation of 10% from the mean yield of the whole area. Solid line negative, and dotted line, positive deviations.

FIELD EXPERIMENTATION WITH TEA.

By

T. EDEN.

In describing to you today some of the work of the past year in field experimentation with tea, I am conscious that I have in the nature of things only very frugal fare to offer you on account of the few months that experimental work has been proceeding, and that my subject seems relatively uninviting in comparison with the others on the programme. To change the figure, I am rather like an architect, building a house, who has at the moment only the foundations to show. Everyone, however, will agree that foundations are important and consequently I propose to deal first with this very matter of fact aspect of tea experiments. Later, I shall discuss the possible form which the superstructure will take, and I hope that in the time for discussion which follows, I shall be able to hear from the meeting about some of the problems you are faced with which may best be settled by field experiments.

In the second and third numbers of *The Tea Quarterly* I outlined the main considerations which must be kept in mind when dealing with experiments, and now that a certain amount of data is available on the points there considered, I wish to give some illustrations of those points. In so doing, I shall be amplifying what has already been said in a briefer form in the Annual Report. I hope that what I say now will help in the interpretation of that report.

Whenever field experiments are mentioned, mention is also made of soil and bush heterogeneity. If there is any doubt of the invariable existence of such inequality, it can be dispersed, I think, by considering the yields of the Uniformity trial now proceeding on The Scrubs Estate. Figure 1 (*a*) represents the results of a single plucking of 2 acres of tea which was specially chosen for its apparent uniformity. The explanation of the figure is as follows: The average yield of the individual plots, based on the yield of the whole area, was taken as 100 units. Starting from this figure, the deviations of the yield of individual plots were calculated, and the square in the diagram corresponding in position to the plot on the field shaded to mark the magnitude of that deviation. Each stroke of the shading represents a deviation of 10 per cent. Where the deviations were positive, i.e., the plot was a better yielder than the average, the shading is in broken lines; where negative, the lines are solid. Blank squares represent plots not more than 5 per cent. from the mean. The diagram thus shows that the field is markedly uneven, but that there is, apart from local heterogeneity, a regular drift from the bottom left to top right hand corner.

Starting with, let us say, one of these small plots, it is obvious that it has little chance of being representative of the whole area; even four plots scattered about the whole area would not be representative. In order to obtain reasonable representativeness, therefore, we shall have to use a greater number of plots than four, or, if we decided to have only four, the plots must be larger. In practice both methods are used, but since it is easier to deal with a small number of plots than a large, it will be as well to see whether we can make the plots more representative by using larger plots first of all.

Figure 1 (*b*) shows what happens if nine of these individual plots are united to form one plot. The drift in productivity is still evident as of course it must be; but general heterogeneity is not so evident. On simple inspection, any one of these plots is a better sample of the whole area than the smaller ones.

Now in calculating the error of a number of plots, it is just the deviations given in these examples that are used. The greater the deviations the greater the error, and the more unrepresentative of the whole area are the plots chosen to represent it. It is this idea of representativeness in connection with error that I wish to stress, and with the aid of these diagrams, to make more tangible.

We can now pass on to the more precise demonstration of the way in which plot size affects error and representativeness. In figure 2 the error is plotted against the plot size, and as will be seen the larger plots have the smaller error, as the two examples quoted would lead us to expect. There comes a time when this increase of plot size is having little effect, and when other means must be used to reduce the error. An increase in the number of plots used for each treatment will provide this, and the dotted line shows how the error decreases as we take larger numbers of plots. In general, a number of plots scattered about the area will produce a lower error than a smaller number of larger plots occupying the same area. As before stated, it is the practical advantage of dealing with fewer plots which makes us choose first the enlarged plot method even though its results are not so satisfactory.

With a crop like tea, which is harvested so frequently, we can use not only a number of plots at the same time in reducing error, but also get the benefit of a large number of harvests. With an annual crop, a season must elapse before results are obtainable, and a period of years before this time replication can be used. Not so with tea. Each plucking can be taken as an answer to the question, i.e., as a separate experiment, and over a pruning cycle from 20 to 50 such answers are available. In this way the error can be reduced if the results for the separate pluckings hang together. If they do not, then there is no advantage in dealing with a very large mass of figures when equally good results can be obtained from the few available from the total yield over the whole pruning cycle. Figure 3 shows how the

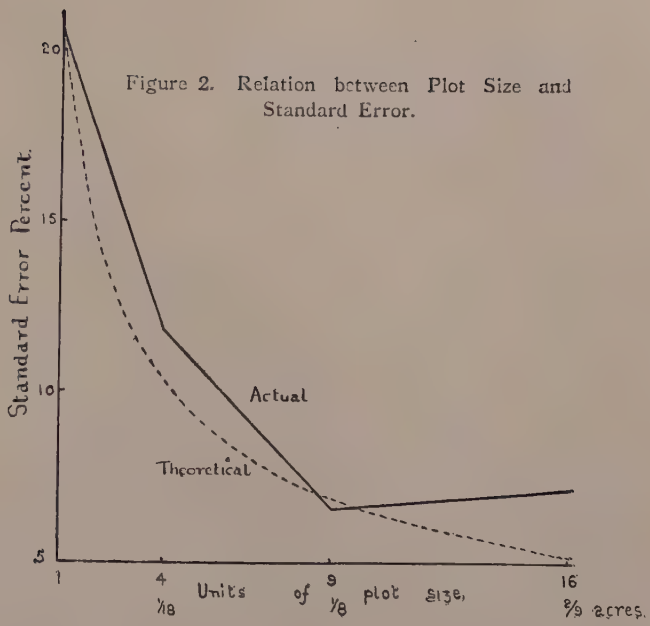


Figure 2. Relation between Plot Size and Standard Error.

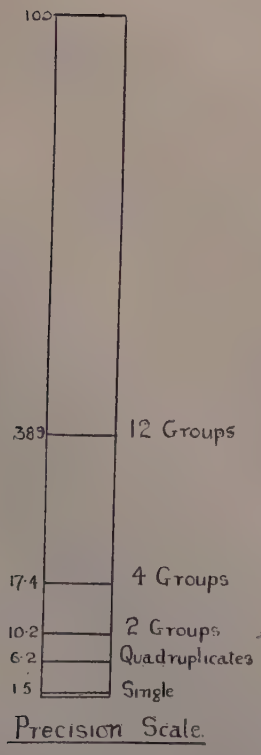


Figure 4

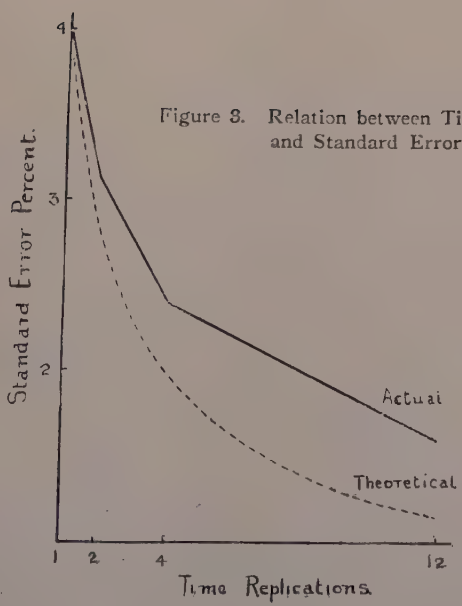


Figure 3. Relation between Time Replication and Standard Error.

error is reduced by treating 12 pluckings first as a total harvest, then as two harvests containing 6 pluckings each, then as four harvests of 3 pluckings each, and finally as twelve individual harvests. The results show that the yields hang together sufficiently well for the advantage of the replication to tell every time. This example is given as an illustration of the possibilities. To treat every plucking as an answer to the experiment would involve calculations the labour of which is not worth the improvement that results; but a scheme whereby a whole pruning cycle is divided into half a dozen periods, treated as independent estimates of yield, would in the light of these results, reduce the error considerably, and would be well worth while.

Let us now, therefore, put together the results so far obtained, and see what sort of progress has been made. For this purpose I will refer you to the diagram of the precision scale (Figure 4). Without going into the statistical principles involved in the setting up of such a scale, it will be sufficient to indicate its meaning. On this scale an error of 10 per cent. has been given a value of one, and an error of 1 per cent. a value of a hundred. The former value is roughly the size of error encountered in many insufficiently controlled experiments; the latter the value at which we aim. It will be seen that a very great improvement in accuracy has been made at each step in the design of which I have been speaking, and the final result is over twenty-five times as accurate as the first, measured in this way.

In concluding this section of the paper, I wish to make three practical points in favour of this search after methods of reducing error. In the first place, the lower the error the more chance we shall have of settling a question beyond doubt in a reasonable time, which is a point of view all will appreciate. By using other means to reduce error besides larger plots and more plots, we shall economise land and thus have room for more experiments. The available land for experiments on St. Coombs is by no means elastic and inexhaustible. The third reason is that if we have to carry on an experiment for a long time in order to reduce our error, certain plots in the experiment, those which are deficiency plots for instance, are getting progressively worse as time goes on. With an annual crop this is not so serious as with a crop like tea, because one starts with a perfectly new crop each time and has only the soil deterioration to contend with. With tea there is the deterioration of the bush too. Bushes which have thus suffered in an experiment will take all the longer to recover before they can be used as normal bushes for a fresh experiment. It is therefore doubly expedient to be able to settle questions in as short a time as is possible consistent with certainty. To my mind these reasons are ample justification for this type of work. I see the possibility of reducing the error of field trials to about two per cent. which is substantially lower than the errors of any of the tea experiments. the published data of which I have examined.

The question of design of experiments depends upon the problem to be solved, and for that reason, before we start experiments which are to be continued for some time, we must be assured that the most useful problems are being tackled in the best way. I wish to mention what in my limited experience appear to be four of the most important problems that demand field work.

The first is concerned with nitrogenous manures. At present, as I have had occasion to remark before, Ceylon is spending a good deal on costly nitrogenous manures of the organic type. Under conditions of poor humus supply, this expenditure may be inevitable, though I am scentical about the necessity of introducing into manure mixtures quite the variety that is common. The practice of intensive green manuring is growing, and the relationship of artificial manuring to that of green manuring is one which I believe to be important. This relationship is not one which can be settled entirely by laboratory investigation, though that will help. I would propose as one investigation therefore, a trial of a standard nitrogen mixture against the so-called cheaper soluble nitrogen both on soils well green-manured and not green-manured. There is reason to believe that the cycle of changes in the soil in the first case may be different from the cycle in the second. This experiment might involve questions of time of application. In order better to define my position I would say that on the strength of our present knowledge I do not recommend the wholesale replacement of organic nitrogen by inorganic salts.

Secondly, there is the question of green manures, particularly, ground crops. The harm that heavy rain does to a soil is not confined to the beating action of the rain which can be modified by shade trees. Where the ground is non-porous owing to alternate saturation and baking, a great portion of the rain flows off to the drains, because the ground does not absorb it, and carries with it valuable soil. A cover crop not only helps to stop the wash, but, by the penetration of a finer root system than shade trees provide, and by the humus accumulated, makes the soil more absorbent.

Now with respect to a ground crop, apart from the question of what to grow, there is the question of how to grow it. I am convinced that the secret of success with green manures in tea does not differ in principle from that for the other crops, and that it lies in management. Experiments on the growth of green cover crops and cultivation of the soil under them will repay study. By cultivation I mean mechanical cultivation in its restricted sense. So far no experiments seem to have been done on the management of cover crops from this point of view—how long to let them grow, how and when to fork them in so as to benefit to the utmost the soil and the tea, and to ensure a good recovery of the ground crop itself.

Thirdly, there is the question of potash in the economy of the tea bush, and here I think it will be a question not merely of establishing whether as between a 'potash' and a 'no potash' plot there is a difference, but of seeing what various quantities of potash can do in conjunction with varying quantities of nitrogen; a result with potash at one level of nitrogen supply does not always apply at a different level, according to the results obtained by Dr. Fisher and myself at Rothamsted. Moreover this type of experiment has recently been shown by Maskell and Balmukand to offer from physiological considerations a better answer to the problem of how much nutrient there is available in the soil, than has previously been given by empirical chemical methods.

Finally, I believe a really useful purpose would be served by some well-controlled liming experiments. There is little doubt but that the degree of reaction which is best for tea is not best for leguminous crops. If we are to grow both together, it is incumbent on us to find a degree of reaction which, whilst benefiting the leguminous crop, does not adversely affect the tea. A policy which is satisfactory with respect to the growth of one crop may need some modifications when it is grown in association with another. This is not a simple problem, but there are not yet sufficient grounds for generalisation.

There is one other aspect of the experiments which I have not touched upon which has probably been uppermost in your minds during this paper—that is, Co-operative Trials. If experiments are to be thus complicated, how can they be done on estates, and if they are not done on estates, how can the effect of varying climates, etc., be tested with respect to treatment, for it is unlikely that the results reported from the central research station will have a universal application.

The following suggestions are purely my personal view and have therefore no Institutional authority. They are the result of a fairly extensive experience of co-operative experiments. I think it would be unwise to contemplate an extended series of co-operative experiments on estates. My experience with annual crops goes to show that with the greatest help and keenness on the part of farmers, it is difficult to ensure the perfect conduct of a field experiment where constant individual care and supervision is in the nature of things not possible Without this and without an experiment of a size which few farms and estates can contemplate, the results frequently do not, in my experience, justify the expense of time, labour, and material. With an annual crop which can be visited by a scientific officer, if need be, at manuring, seed and harvest time, I have had good results. The frequent plucking of tea introduces a complication which seems to me insuperable. My experience with the Uniformity Trial is that someone reliable must be present all the time. I would therefore propose that instead of trying multifarious treatments about which one knows

little on estates, and calling them scientific experiments, they should be tried first of all on the Institute's estate with as great an accuracy as is possible. Then after weeding out unsuitable treatments, one may try the successfuls and doubtfuls on a sub-station chosen on account of its soil or climatic characteristics. This station would be under the personal charge of an assistant trained in the strict methods in use at the central station, and constantly visited and checked. The reduced number of treatments tried should make it possible to secure the necessary accuracy at the sub-station. From sub-station results the general efficacy of a treatment or its different behaviours under different conditions would be available. Following this, demonstrations which do not purport to be accurate experiments, but object-lessons of the proved results, should be done on estates, and I personally should be glad to render all the assistance necessary. In this way, I believe, time and money will be saved, and the disappointment of working perhaps for years without getting satisfactory results avoided. At the same time, the connecting link between the experiment station and the practical estate will be firmly maintained, as I believe it must be if our work is to achieve success.

DISCUSSION.

Dr. C. H. Gadd said that at one time it was considered a very simple matter to carry out field experiments. Unfortunately, such experiments had proved of little value because the elements of chance entered into them too greatly. The final test of any agricultural hypothesis, whether that hypothesis is derived from observation in the field or from accurate experiments in the laboratory, was field trial. The methods of field experimentation therefore had to be improved in order to make the test more conclusive. The combined work of mathematicians and field experimenters had brought about the necessary improvements in the technique, but the methods were no longer simple. That perhaps was to be regretted. But field experimentation must be regarded as a science, like Chemistry, and the methods to be adopted for the elucidation of a problem must be left to the specialist. The agriculturist who sent a sample of manure or soil to a chemist for analysis did not concern himself with the methods of analysis used by the chemist; his concern was with the answer provided by the chemist's analyses. In the same way, the design and conduct of a field experiment had to be left to the specialist. In Mr. Eden, the Tea Research Institute was fortunate in having an officer to whom this branch of work could be left with every confidence. His paper today indicated that he was making a close study of the principles of experimentation applied to tea.

Mr. Eden had outlined four important questions which required answers from field experiments. He doubted that, important as those questions appeared, the whole meeting would agree that they were the most important or that they should be the first to be tackled by the Institute. A list of all the problems requiring research would be very lengthy. It was obviously impossible for the Tea Research Institute to attempt the solution of them all at once. He would perfer to see a start made with a small number of experiments which could be done with such precision that the answers obtained could be relied upon, rather than that they should attempt a large number of experiments at the onset. If that was to be done a short priority list was necessary. He hoped that those present would

express their opinions not only on the four subjects Mr. Eden had outlined, but also give their own views on the matters they considered to be important and requiring immediate attention. That would assist in the selection of the most suitable subjects for their first experiments. He hoped that members from different districts would let them know of the matters about which they required information.

Mr. W. A. Perera asked if anything were known of the optimum moisture content of the soil for turning in green manures. He was of the opinion that the results obtained from green manuring were affected by the conditions under which the turning in operation was done.

Mr. Eden in reply said that such a problem as Mr. Perera's was one of the questions that fell into the group of questions of management upon which he had just laid emphasis. In any comprehensive experiment with green manures it would be necessary to follow the breaking down of the green stuff in the soil. He was of opinion that other factors, in the successful use of green manures, such as the age of the green manure crop, would be so important that in all probability the planter would not be able to wait till his optimum soil moisture was attained, supposing such a criterion could be established. He saw no reason however why from experiments on St. Coombs the general soil moisture condition for successful incorporation of green manures should not be forthcoming.

Mr. D. J. Malcomson emphasised the great cost which an estate entailed by its manurial programme, especially by the use of expensive nitrogenous manures. He thought that information regarding the use of organic and inorganic nitrogenous manures, in terms of what such manures actually cost the estate, and what they produced would be very useful. The same applied to the potash question, and the relative merits of the varying recommendations as to time of manuring. Such problems were vital because in the aggregate they represented the expenditure of large sums of money which they were possibly wasted at the present time.

Mr. Eden replied to the effect that there was no reason why the experiments should not be properly costed. The value of such costing would depend on two things, firstly, confidence in the reliability of the experiments and secondly, confidence in the applicability of the results of the experiments in general practice. He had outlined the method by which he hoped to obtain those necessary conditions, and the type of experiment which would give the desired information about organic nitrogenous manures. When the time came he would need the co-operation of someone more experienced in costing than himself, but costing was a matter which he thought should be carefully watched.

With regard to the question of potash and the time of application, he remembered that at the last Department of Agriculture Conference a question was sent in by one of the District Planters' Associations which was never answered. It asked for information about the average quantity of nutrients removed by an average tea crop. There were to his knowledge no reliable data on the subject, but he would warn them that the total quantity removed was not a very important matter. It bore little or no relationship to the quantity it was necessary to apply to the soil in order to raise a crop of the size considered. The analysis of the crop could however be made to yield data from which any differences in rate of uptake from time to time in the pruning cycle could be detected. Such work was already in progress, and when complete its bearing on time of application of manures would be examined. The work was complementary to that undertaken by Dr. Evans who was actively co-operating in it.

Mr. L. A. Wright asked whether the effect of manurial treatment or the quality of the tea would be investigated.

Mr. Eden in referring the question to Dr. Evans declared that the experiments would be designed with that end in view, and that the best means of tackling that aspect were already a matter of discussion between himself and Dr. Evans.

Dr. Evans assured Mr. Wright that when the large scale experiments on yield were actually in progress, the question of quality would receive his consideration as well.

Mr. A. Westrop, speaking as one whose time was devoted to the sale and distribution of fertilisers, expressed his gratification at the prospect of accurate experiments which would enable them to provide fertilisers and mixtures of proved value. In the past they had been forced to rely to a far too great extent on other people's experiences rather than on Ceylon experience. They would be only too glad to get away from hearsay evidence. He did not mind what fertiliser they sold so long as its results justified the expenditure. They were not out to push any particular manure. They made or lost just as much on one kind as on another.

He would like to draw the attention of those present to a new aspect of the fertiliser trade, that dealing with concentrated fertilisers. The setting up of such concerns as the Imperial Chemical Industries heralded the production of new fertilisers such as Urea, a fertiliser which was highly concentrated, kept well, meant less in freight charges, and had been found in the case of rubber to be of greater benefit, unit for unit, than other types of nitrogenous manures. They had no experience of it with tea, but it was one of the cheapest fertilisers at the moment.

Mr. Eden remarked that his position that day was that of a lawyer pleading his case. He was endeavouring to convince the company of the importance of good and accurate experiments. Mr. Westrop had given him another point. The speaker had spoken of the benefits derived from the use of Urea. Now those benefits were doubtless real, but they were not large. The difference between one form of nitrogen and another was not going to be 100 per cent. but more like 10 per cent. Nevertheless a 10 per cent. difference was important to the industry. He had had experience with several of the new nitrogenous fertilisers, including Urea, and he could assure them that in order to determine the real merits of these new fertilisers, they would need highly organised and accurate experiments. It was because they realised this that they were putting time and energy into what might seem a very academic aspect of field experimentation.

The Chairman, in thanking Mr. Eden for his paper, referred to Mr. Eden's experience of field experiments and their technique at Rothamsted. He thought that by means of the Sub-Committee on Field Experiments of which Mr. Eden was a member, they would be able to inaugurate a sound experimental programme. If there were any who had hesitated to express their views at the meeting, he would ask them to communicate directly with Mr. Eden at Nuwara Eliya, or to discuss them with him personally.

They were going to make a start on St. Coombs on a small acreage of mature tea, whilst the larger experimental area was being brought into bearing and adapted to their needs.

BIOLOGICAL CONTROL IN ENTOMOLOGY, WITH SPECIAL REFERENCE TO PESTS OF TEA.

By

S. STUART LIGHT.

It will be my endeavour in this paper to convey to you an impression of, firstly, the part that insects play in Nature in the control of agricultural pests, and, secondly, the use that has been and is increasingly being made of beneficial insects in economic entomology.

Before proceeding to give an account of the control by insects of pests on tea estates, I wish to mention a few instances of the natural suppression of pests on crops in general.

The Argentine ant, a small but exceedingly ferocious member of this group of insects, although itself a pest of the utmost importance, does a great deal of good by destroying other noxious insects. A certain fly, attacking millet in Louisiana, is controlled principally by this ant, which is also one of the foremost enemies of termites in regions where it flourishes. Another ant, known in Gautemala as the "Kelep," was recorded by Howard in 1904 as being such a formidable enemy of the Cotton Boll Weevil in that country that a regular harvest of cotton could be procured, even under conditions favourable to the weevil.

A graphic example of the control exerted over grasshoppers by Sarcophagid parasites has been recorded by an entomologist in New Mexico, who "found thousands of grasshoppers that had been killed by Sarcophaga larvae lying dead on the prairie. In some places as many as 15 per square foot were found in this condition." Another report, referring also to the effect of Sarcophagid flies, runs as follows: "Crops badly injured by grasshoppers; latter now dying by millions. Farmers say that 10 days ago they had no hope of getting crops, but now prospect is good."

These are but a few of the innumerable instances that could be quoted, but they will serve to illustrate the point.

The following are similar examples that have been observed in connection with insect pests on tea estates in various countries: A species of Nettle grub, *Setora nitens*, which is an important pest of tea in Java, is often reduced considerably by a parasitic fly called *Chaetexorista javanae*. The value of the parasite is recognised to such an extent that the cocoons of Setora are collected regularly and kept for some days in order to enable the parasites inside to escape and continue their good work. An allied parasite, *Exorista heterusiae*, is undoubtedly a considerable check on Red Slug, *Heterusia cingala* in Ceylon. Towards the end of an attack of this pest on tea, it is common to find numbers of caterpillars in a parasitised condition. The same thing has been observed in the case of nettle grubs in this

country, especially with the Fringed Nettle Grub (*Natada nararia*), but the parasites involved here are not flies, but wasps of the family *Braconidae*. The case of parasitism mentioned in the Annual Report of the Tea Research Institute for 1926 is worthy of note, in which an outbreak of one of the larger nettle grubs, *Thosea cana*, was practically suppressed by an *Ichneumon* wasp, 90 per cent. of the caterpillars being found to contain one of these parasites.

The activities of Helopeltis in Java are often reduced appreciably by a Braconid parasite, *Euphorus helopeltidis*. It is recommended by the Tea Experiment Station that during outbreaks of Helopeltis, specimens shall be sent in from estates for examination. If 50 per cent. parasitism or over is reported, the adult bugs only shall be collected, leaving the younger stages, in which the parasite may breed unchecked.

The common Albizzia Caterpillar (*Terias silhetana*) is attacked in Ceylon by a Tachinid parasite, which must be a considerable controlling factor, since the caterpillars often show a high percentage of parasitism. On the other hand, Tea Tortrix, although it is attacked by a variety of parasites in its egg, larval and pupal stages, does not appear to be checked to any appreciable extent by beneficial insects. I, personally, have seen a fair degree of parasitism produced by only one species, the Ichneumon *Phytodietus capuae*. In one field on an estate suffering from tortrix in Maskeliya, I found 50 to 60 per cent. of the caterpillars parasitised. But Phytodietus is not a very effective parasite, commonly as it occurs, on account of the fact that the larva is an external feeder, becoming attached to the back of the Tortrix caterpillar just behind the head. If the adult parasite lays its egg a little too far back or too low down on one side, this brings the developing larva within reach of the Tortrix caterpillar, which frequently turns its head round and bites off the parasite. Caterpillars are often found showing the scars where parasites were once attached.

Antram in 1911 gave an account of the value of Coccinellid (ladybird) and Staphylinid beetles in controlling the activities of Red Spider on tea. On one estate the beetles were mainly instrumental in preventing severe loss, exterminating the mites before they could do much damage. In Ceylon however, mites appear to be little affected by enemies of any kind. The only definite predator that I have discovered, and this on one occasion only, is a small Anthocorid bug, which in the laboratory fed voraciously on Yellow Mite, Scarlet Mite and Red Spider, and attacked also the eggs of the last two.

Tea Aphis (*Toxoptera aurantii*) is subject to the attacks of a variety of parasitic and predatory insects, and undoubtedly is often controlled by these. The larvae of Syrphid flies (Hover Flies) are perhaps of most importance in this connection: on one occasion I bred out 57 flies, comprising at least four different species, from one cigarette tin full of flush infested by the aphis.

Many instances are on record of the successful introduction of beneficial insects into various countries against pests of importance, but no more oustanding example exists than that of the ladybird beetle *Novius cardinalis* which was used so effectively against the Fluted Scale (*Icerya purchasi*), a serious pest of citrus and other trees. Introduced first into America from Australia, its success was immediate, and subsequently it was employed for the control of the Fluted Scale in countries all over the world.

The grubs of cockchafers, or White Grubs, similar to those that gnaw through the roots of tea seedlings and young plants in clearings, have been effectually dealt with by means of a certain family of wasps known as Scolids. One of these, *Scolia manilae*, was at one time introduced for this purpose into the Hawaiian Islands. According to one investigator, the abundance of grubs, which were a serious menace to the sugarcane crop, amounted in 1927 to as many as 70,000 per acre. In two years *Scolia manilae* had so reduced their numbers that the investigator could find barely 80 grubs to the acre.

Two beneficial insects are of world-wide employment at the present time: These are the Chalcid parasite *Aphelinus mali*, which has been used in many countries with marked success for controlling that scourge of the orchard, the Wooly Aphis, and the ladybird, *Cryptolaemus montrouzieri*, employed for the subjection of various scale insects. The former is a native of N. America, where it keeps the Wooly Aphis in check, and was first imported into S. Africa for the same purpose. The home of Cryptolaemus is Australia, and it first came into prominence by being shipped to California chiefly for the control of citrus scales. From California it has been exported all over the world.

It may be mentioned incidentally that no country has such a record of successful introductions of beneficial insects as the Hawaiian Islands. From all over the world species of parasites and predators have been shipped to these Islands to deal with the pests of sugarcane and other crops, and the benefit they have bestowed on the industries concerned are almost incalculable.

But although certain species, such as those I have mentioned, have shown a remarkable adaptability to varying conditions, and there has been no question of their value in controlling agricultural pests, it must be confessed that such instances are the exception, and many failures have gone to the making of every success.

A study of the important insect pests of any country, particularly of the more recently civilised lands such as Australia and the United States, reveals the fact that many of them have been imported from other countries. The reason why so many imported insects become successful pests is that with the land of their birth they leave behind the natural enemies which for untold ages have preyed on them and

kept them in check. On arrival in a new country, the insect finds its habitual foes absent, and it is easy to understand that the potential enemies which it encounters require some time in which to adapt themselves to their new prey, and to take the place of its original foes. In many cases they are never quite able to replace the latter, and the pest continues to flourish.

The employment of beneficial species against an insect pest takes one of two forms, viz., (a) the artificial propagation, by breeding and distribution of the natural enemies that are already tending to control the pest in its home country; or (b) the importation of its natural enemies from abroad. In the first case the principle involved is the maintenance of a large stock of the insects to be used so as to be able to liberate a supply when and where these have, through the decrease of the pest or from other causes, reached a low ebb. It is seldom possible to establish a native parasite satisfactorily by any degree of propagation.

Where parasites are introduced from abroad, this is done with the hope of getting them established in the home country. This, as I shall show later, is far from a simple matter. But when fairly established there is always reason to expect that they may become an important factor in keeping the pest under control. And successful establishment usually obviates the necessity for maintaining a constant supply under artificial conditions. It is with this second form of employment that I propose to deal principally.

When it is decided to attempt the control of an insect by the importation of parasites or predators from abroad, usually the first thing to be done is to discover which is its native land, and this, in itself is a task of no small degree. This difficulty overcome, a careful study must be made of the life-history of the species and the natural enemies that keep it in check. Usually, one or two species are of outstanding importance in this respect. These, then, are selected, and consignments are carefully packed up and despatched to their required destination. Here again difficulties confront the entomologist, for many may die on the voyage, and often the survivors are hardly able to exist. On arrival the insects are either liberated at once in the affected regions, or, more usually, are placed in suitable breeding cages, and an attempt is made to propagate them for future use.

If the breeding proves successful, batches are distributed to the pest-ridden centres, and are liberated there. The final establishment of the parasite or predator depends largely on its adaptability to foreign conditions. Unfortunately mere establishment does not necessarily spell success; many adverse circumstances may arise which frequently render the introduction void, and, even in some cases, actually harmful. The following are the principal factors to be taken into account in the introduction of natural enemies:—

The cost of the importation and propagation must naturally be carefully weighed in consideration of its value to the crop concerned. It must be remembered that positive results of any value can hardly be expected for the first two or three years.

The relative rates of reproduction of host and enemy must be studied. The latter should breed at least as rapidly as its host; very often a more rapid development is required. The necessary rate of reproduction in the case of predatory insects depends largely on their "devouring capacity,"—for instance, a predator (as is the case with some ladybirds that feed on aphides) which is capable of demolishing 100 or more of its victims in a single day, does not require to reproduce very rapidly in relation to its host. It sometimes happens that the parasite may actually breed too quickly, for this has occurred in the use of *Aphelinus mali*, already referred to in this paper. In attempting to establish this parasite in England, it has been found that it breeds so much more rapidly than the Woolly Aphis that it soon exterminates it locally, with the result that there is, for a long period, nothing left for it to feed upon, so that it becomes extinct. The only remedy for this would be to keep going a large and constant stock of the parasites, so that deficiencies might be supplied as they occurred.

The relative activity of the two forms opposed is another factor that may influence the situation. Stationary hosts, such as scale insects, are readily attacked and subdued, while active forms, especially winged hosts, which are capable of ready migration, present a far more difficult problem. Activity in the species used for control is therefore desirable.

The question of breeding the insects that are used is obviously of the utmost importance. Some species are able to adapt themselves easily to foreign conditions, while to others varying climatic and other influences form a considerable or even insuperable barrier. It has been observed frequently that a parasite which has been most effectively introduced against a certain pest in one country proves of no avail against the same pest in another land. Again, it is found difficult to rear many forms in capitivity, while others lend themselves readily to artificial conditions.

Hyper-parasites (that is, insects that parasitise the parasites) form a serious menace to the progress of many beneficial insects. In the same way possible parasites of imported predators have to be taken into account. Sometimes, in the case of an important pest subject to the attacks of a variety of natural enemies, the introduced form goes ahead rapidly, and secures a monopoly of its prey; the result is that some of the natural enemies already present are deprived of their normal food supply, and may turn their attention to the newcomer, which suffers in consequence.

A study must be made of the treatment accorded to other important insect pests in the neighbourhood of the primary pest. When the treatment comprises spraying or other chemical measures, it is often impossible to utilise natural enemies in such an area, since they may themselves fall victims to the poisonous substances employed.

There is always to be considered the possibility that the imported species may in time turn its attention to other harmless or beneficial insects, in addition to, or in place of, the one intended, and thus largely neutralise its practical value. For instance, a certain parasite introduced into the United States against the Gypsy and Brown Tail-Moths, has become an established parasite of some 25 other lepidoptera. For this reason it is desirable that the insect employed should not have too wide a range in feeding habits. Specific forms are usually to be preferred, yet at the same time, it is often of value that the imported foe should possess secondary hosts to which it may turn its attention if at any time the supply of its normal prey falls to a low level.

A great deal of work has been done in America, notably in connection with the Gipsy and Brown-Tail Moths, on the "sequence theory" of control, the ideal aimed at being to establish a perfect series of parasites controlling the pest throughout its life,—egg parasites followed by larval parasites, and so on. But the perversity of Nature makes this desirable state of affairs practically unattainable.

The utilisation of native parasites is of much rarer occurrence and few successful instances occur of the use of such parasites, other than various species of Trichogramma. The necessity for maintaining a large supply of parasites may entail considerable cost, when carried on a large scale, and is almost impracticable unless the parasite is, like Trichogramma, of minute size.

Little has been done towards the control of tea pests by beneficial insects. The encouragement of certain parasites in Java has been referred to. It is interesting to note that a species of ant, *Dolichoderus bituberculatus*, has been used to control Helopeltis on cocoa. In India I do not believe that anything in this line has been carried out. E. E. Green once imported a predatory beetle into Ceylon in the hope of using it against Shot-Hole Borer, but the experiment was doomed to failure from the first since the beetle proved much too large to enter the galleries of the borer. Nettle grubs are insects that should lend themselves readily to the action of imported parasites. A suitable species of Braconid wasp might be obtainable for this purpose.

In the present attempt to propagate *Trichogramma erosicornis* for the purpose of controlling Tea Tortrix, we are dealing with a native parasite, and one which rarely, apparently, exerts an appreciable influence on its host. Considerable difficulty has been experienced in breeding it under the very artificial conditions in which it has been

deemed necessary to carry out the experiment, and it is evident that it does not adapt itself so readily to such conditions as the allied species *Trichogramma minutum*, which has been successfully employed for a similar purpose in America. It is likely, though not certain, that better results would be obtained by the importation of the American species into this country, a procedure which could readily be carried out at little cost, and which, in my opinion, would be well worth the trial.

DISCUSSION.

MR. L. A. WRIGHT asked if Mr. Light could supply them with a little more information concerning the Argentine ant which he had stated to be one of the foremost enemies of termites, and whether it would prey on Calotermes. Calotermes was a serious pest in Ceylon, and anything which could be done to fight it would be of extreme value.

MR. LIGHT replied that it was unlikely that the Argentine ant would enter a tea bush to attack the termites inside. Moreover the ant was itself a serious pest and one which attacked many different crops. It had even been known to attack babies in their cradles.

DR. GADD said that the control of insect pests by their natural enemies was a fascinating subject and one of great importance to agriculturists. Owing to the nature of the tea crop, the use of poisonous chemicals in controlling the pests of the tea bush had a very limited value, and wherever possible biologic control was to be preferred. The main advantage biologic control had over chemical control, when an imported parasite was used, was that the former was permanent while the latter was purely temporary. If a spray schedule was not adhered to, the pest took advantage of the fact and efforts towards control were neutralised. Moreover the cost of chemical control was a continuous drain on any agricultural industry, whereas with biologic control the cost was limited. Expenditure ceased when the parasite was successfully established. Biologic control by means of an indigeneous parasite stood on the same footing as chemical control as regards cost. The parasite had to be maintained in large numbers under artificial conditions, protected against its enemies and adverse climatic conditions, and liberated when and where required. This meant continuous breeding with its accompanying cost. Some explanation might therefore be necessary why the Tea Research Institute in its initial attempt to establish biological control had selected an indigenous parasite with which to work.

It should be understood that the mere fact of importing a parasite did not necessarily mean success. From enquiries abroad Mr. Fetch obtained a list of possible parasites that might be used against Tortrix. The list included parasites of the pupa, larva and egg. It would be agreed that the most suitable stage to destroy Tortrix is while it is in the egg and before it has had the chance to do any damage. On that list was the name of only one egg parasite, viz. *Trichogramma minutum* which is being used, by all accounts with success, in America. From Mr. Jardine's work they knew that a species of Trichogramma existed as an egg parasite of Tortrix in Ceylon and it had been suggested that the species was *T. minutum*. If that identification was correct, it was obviously unnecessary to import that parasite from America. Therefore, they decided to give their own indigenous parasite a chance by using similar methods to those applied in America. The preliminary work in Nuwara Eliya was sufficiently promising for the work to be continued on a much bigger scale. In the more extensive breeding, however, they had met with innumerable difficulties and setbacks with the result that the

work had not progressed as they could have wished. In the meantime the Ceylon species had been identified as *Trichogramma erosicornis,* so was different from the American species, *T. minutum* which Mr. Light suggested should be imported for trial. That suggestion would receive very careful consideration. He would like to see their own species tried out in the field to ascertain what the parasite was capable of doing before labelling the experiment a failure.

Had they selected a parasite of the pupa or larva, they would have experienced similar difficulties. They did not know exactly what species were already present in the Island, and until they knew that it would be a risk to make an importation from abroad. Obviously it would be a waste of money to import something which was already in the Island. The question of the importation of beneficial insects was one requiring careful consideration and investigation. It was possible that one imported as beneficial might prove otherwise. It was a matter which concerned all agricultural interests of the Island and not one particular industry alone, and necessitated close co-operation between the different industries and the Department of Agriculture. It was a matter for congratulation that co-operation existed between that Department and the Tea Research Institute.

THE CHAIRMAN remarked that Dr. Gadd had assisted him by making reference to co-operation between the Institute and the Department of Agriculture. He was pleased that that co-operation existed and he was sure that it would extend not only to the new research institutes they hoped would soon be in existence in Ceylon, but to research institutions all over the world. It would assist them in the general search for parasites to attack the many insects which preyed on their crops. In the tea industry they had several menacing pests, and these were engaging the attention not only of their own Institute but also of the Department of Agriculture. He instanced Calotermes and Nettle Grub. Uva and one or two other areas in that part of the country were crying out for assistance in combating nettle grub which was undoubtedly increasing. He wished to take that opportunity, on behalf of the tea industry of expressing the debt of gratitude they felt they owed to the Department of Agriculture for the co-operation it was affording in combating these serious menaces.

He had recently received a letter from Mr. F. A. Stockdale in which he suggested the advisability of engaging an entomologist to come to Ceylon to study local conditions and pests, and then to travel abroad with the object of collecting parasites for introduction into Ceylon. That question was being considered by the Tea Research Institute, and they would be pleased to know that the views of the Acting Director of Agriculture and the Acting Director of the Tea Research Institute were in accord on this matter.

SOME BASIC PRINCIPLES OF AGRICULTURE AS APPLIED TO THE ESTATE.

By

E. E. MEGGET.

What I have in mind, and my title indicates this, is to set out some principles indicating where plant food is obtained and how it is made available.

Soil can broadly be described as the disintegrated rock covered with the remains of plants spread over a large portion of the surface of the earth. This surface also contains living organisms and variable quantities of water and air, which play essential parts in making this material available.

The rocks from which soils are formed are classified as:—

1. *Igneous rocks* which are caused by the cooling of intensely heated matter; the granites represent this type.

2. *Sedimentary rocks* being those resulting from the settling out of particles suspended in water; limestone is an example of these.

3. *Metamorphic rocks*, being those which have changed in character since they were deposited; the conversion of limestone into marble by pressure and heat is an illustration of this class.

Rocks are rarely homogeneous, that is, alike in all parts. The various components which have a more or less definite composition are called minerals. Of the minerals that are abundant and of the greatest importance in agriculture, we have quartz (silicon and oxygen) which is estimated to form 35 per cent. of the earth's crust, and is practically insoluble in water, so is little affected by weather. Feldspars are the most abundant of all minerals and are estimated to form 48 per cent. of the earth's crust. Part of the constituents of feldspar are called silicates, and from these the plant obtains most of its potash.

The foregoing roughly cover the inert mass which is the basis of soils. To advance another stage, we require to touch on the chemical changes which make the elements available. These changes are numerous and complex, and the same influence which causes their breaking down from the original rocks into soil, eventually leads to their becoming available to the plants. These changes are hastened by the carbon dioxide produced by the decay of organic matter.

Potash constituents may in part be dissolved and carried away in the drainage, be absorbed by the plant, or, held by some of the absorptive constituents of the soil.

Calcium phosphate as it exists in minerals is nearly always insoluble in water, but, through the action of the soil water containing carbon dioxide in solution, it is changed to a more soluble form and becomes available to the plant. Again, in contact with certain forms of iron and aluminium, the calcium phosphate may be changed to iron and aluminium phosphates, and held in the soil in a finely divided condition, which though insoluble in water, can be dissolved by the acid juices of the plant roots.

Absorption of soluble plant food by soil plays a vital part in agriculture. Were it not for this the depletion of fertility would go on at a much more rapid rate than it does. Illustrating this helpful action, if a solution containing phosphoric acid, potash and ammonia is poured upon fertile soil, the water filtering through will be found to be nearly destitute of these substances. This property plays a particularly valuable part in estate culture in view of the adverse influence of steepness and heavy rainfall —conditions not normally associated with agriculture.

Of the elements directly concerned with plant life, carbon is the most important and forms a large proportion of the solid matter of all living beings. The chemical processes of plant life are mainly those in which carbon takes a prominent part. It exists in many minerals and also as a small but important element in the air (carbon dioxide). The carbon in the soil takes no direct part in forming the carbon compounds of the plant, the carbon dioxide in the air being the source of supply. Nitrogen which takes a first place in manurial mixtures is present only in the outermost portion of the surface, the greater portion being present in the air. No true minerals containing it are known excepting those which have their origin in plant or animal life, such as coal or nitrate of soda. In the conservation of these substances, from what is discarded in animal life, from what is discarded by destruction and decay in plant and animal life, we have one of the most important branches of agriculture and one neglected more than any in estate culture. What serves to illustrate this is the general lack of care in handling and conserving cattle and similar manures, leaf droppings and green manurial matter, the indifference to the loss caused by erosion, the destruction caused by burning off clearings and by improvident chena cultivation.

Humus, the product of decay of organic matter, is valuable directly as being the actual source of supply of nitrogen; indirectly, it is of value because it modifies the physical properities of the soil, and by its decay increases the proportion of carbon dioxide in the soil with a consequent increase of the soil's power of solvency. An indirect, but particularly important, effect of these conditions is its reaction on the plant food in the basic mineral portion of the soil. Humus increases the soil's power to absorb and retain water.

Nitrification is the most important process in the feeding of the plant and requires special reference. Nitrogen, as present in soil combinations, is not available for plant food until decomposition, by means of fungi and bacteria, has converted the nitrogen into ammonia and then into nitrates, these being forms soluble in water and therefore available to the plant. Nitrification only takes place in a moist soil and one sufficiently porous to admit air. Denitrification and consequently loss of nitrogen takes place when the soil is not aerated and has the spaces between the particles filled with water.

Having touched on basic principles relative to soil formation, it will be of interest to outline what will give a rough perspective of what might be called supply and demand. As a guide I will make use of the work done by Messrs. Cockran and Hughes in the early 'nineties. We can assume the total weight of the top 9 inches of an estate soil to be 1,000 tons to the acre, and from the data furnished by these gentlemen, the average tea estate soil should contain in that mass $1\frac{1}{2}$ tons of nitrogen and rather over 1 ton each of both potash and phosphoric acid. Availability depends on reactions such as I have already referred to, and from the foregoing it will be understood that a very small proportion only of this material can be used.

A crop of say 600 lbs. tea per acre would remove approximately 29 lbs. of nitrogen, $4\frac{1}{2}$ lbs. phosphoric acid and 15 lbs. potash from the soil.

Water's place in the chemistry and the working of the plant, as well as of the soil is of first importance. In the plant, water is the medium in which raw material is transported from the root to the leaf. There, in combination with the carbon dioxide of the air it is formed into the carbo-hydrates that build up the plant. In considering the part that water plays in this, it is important to bear in mind the enormous loss of soil water that occurs by water in excess of the plant's requirements being given off from the leaf into the atmosphere by what is called transpiration. It is not generally understood that the loss of water is greater during dry periods from a soil under crop than when fallow. Marking this, at Rothamsted during a drought, an area under barley was checked against a bare block, when it was found that to a depth of 54 inches the former contained 9 inches less water than the bare soil did through evaporation plus transpiration. What the latter means is shown by experiments with various plants. I quote the common wild Pea in which for every pound of dry matter in the plant it was found that 477 lbs. of water was taken from the soil and given off into the air by transpiration. I touch on this point as being one to be considered in connection with cover crops during dry periods. The value of a soil can be measured by its retentiveness, and I quote the following as indicating this. Sand in a cubic foot retains approximately 27 lbs. of water, loam 41 lbs., humus 50 lbs.

Now to touch on cultivation. Here we are confronted, and always will be, in the Hills, by the knowledge that while tillage is an essential it cannot be separated from a degree of damage due to varying causes. The evergreen nature of tea and its close planting, the character of the ground to be dealt with, and the difficulty of fitting cultivation into suitable climatic periods, are examples of these causes. In this and in dealing with ground cover we have problems in agriculture almost unique to Ceylon tea culture. In the past the tendency was either to overdo tillage or to neglect it; of the two, while the former can and does cause serious damage, the latter, on the whole, is the more harmful. Improving tilth enables us to get at the store of food stuff natural to the soil, as well as to increase the value obtained, from the application of artificial manure. The improvement to the sub-soil by tillage, and I include full use of green matter in this, keeps feeder roots well below the surface, thus making them less susceptible to the influence of drought. Evaporation is reduced by a looser state of division of the soil, which also facilitates the regrouping of chemicals, thus making for solubility.

There has recently been considerable correspondence in the Press regarding silt and cross checks in drains. Without wishing to detract from the credit due to the gentleman concerned, I might mention that probably 30 years ago such work was carried out on a considerable scale by, among others, the late Mr. W. B. Jackson on the Hauteville Group. The object then aimed at was a dual one—by the use of deep silt pits to minimise the waste of water-carried plant food, and to open up the sub-soil by the seeping of the water in the pits. To my mind, however, this system has a limited value. Something is required to retain *in situ* what is otherwise carried off into the drains in solution or in suspension. That again is a question of good tilth, the effect of which will be to enable the ground to absorb much of the rain that otherwise rushes over the surface, splitting up what we and nature are endeavouring to retain in the physcial combination necessary for good growth, and giving the fortunate paddy field owner on whose land they are eventually precipitated, the benefit of the valuable soils carried off.

Surface wash is a big question and rightly one on which considerable attention is being focussed. I will not touch on the familiar causes of this, but will mention one, wind damage, as a matter that is not considered as much as is warranted. A common sight on exposed faces is to find bushes standing on pinnacles. Scraping and wash are factors, but going back ages before tea was thought of, the basic cause is exposture and wind damage. Leaves fall and blow away, soil particles follow suit, and it is worth while in such areas to specialise in ground cover and wind breaks even to the extent of for a time ignoring the tea bush. Nature is a wonderful schoolmaster. A comparison of the soil over such areas with that over adjacent but better protected ones is an object lesson of what, with infinite care of detail, has been

going on over hundreds of years. By artificial means we can expedite the process of improvement, but we shall fail if we do not keep in the foreground the fact that humus is our objective, directly because of its plant food value, indirectly because of its influence in unlocking food stuff from the original soil, and finally, because of its power of retention. As a side issue we should bear in mind that this retentiveness lengthens the period over which the bush benefits from favourable climatic conditions and reduces the adverse influence of droughts.

The uses and abuses of artificial manures and compost come within the scope of this paper. According to figures in Ferguson's Directory in 1926 Ceylon imported 125,700 tons of artificial manure valued at Rs. 15,276,900/-. To this, when looking into the matter from our point of view, we require to add dealer's profits and transport to the estate. The bill is a big one and perhaps not thought of when we grumble at the extension of our scientific staff and research departments. To insure soundness in ingredients, and economy in expenditure, we require expert advice. One has only to study the varied mixtures used over similar areas to realise how much we are at the mercy of fads and fancies. In detail many of these mixtures are expensive because of their solubility and, unless they are got into the ground soon after mixing, chemical reaction takes place under conditions that result in waste of money. Further it is not an uncommon sight to see supplies exposed to the elements, conditions that mean serious deterioration. It is as well to bear in mind that the concentration of ingredients as obtained in artificial manures is a business convenience, and that once in the ground these supplies are readjusted so that they have their effect as a small though important part of the soil mass. To go back, as a means of solving serious transport problems, concentration was a necessity, and the movement of more bulky materials was prohibitive. Light lorries and feeder roads are already making themselves felt, and will in time drastically alter our methods, especially in the bringing into better use of what nature provides for us. I refer to any form of organic matter, weeds, leaf droppings, factory refuse, green manures, etc., cheap and valuable elements that, incidental to transport difficulties, have in the past been neglected.

In passing, taking details out of the import figures for 1926, I find that 35,700 tons value Rs. 4,350,000/- of groundnut and castor cake was imported that year, presumably from India. Our Agricultural Department staff may be able to tell us whether Ceylon could not profitably supply all or part of these or similar organic manures. One can only make an approximate estimate of what is annually spent on the manuring and cultivation of tea properties, but an average of 8 cents. per lb., say, Rs. 16,000,000/-, would not be far out. Again without a census, the allocation of this is speculative. If we take Rs. 13,000,000/- as spent on artificials, and a round Rs. 3,000,000/- for labour, green manuring, etc., we have figures that will serve to mark the magnitude of this branch of our work.

The uses and abuses of artificial manures as a whole opens up a wide field for discussion. Touching on this as a detail and a very important one, I would make the point that the ratio between expenditure on artificial manures and cultivation with all its connected work (such as green manuring, and use of available organic matter) could be adjusted, substantially decreasing expenditure on the former while at the same time increasing it on the latter. That appears to fall in with present day planting opinion, and while guiding the movement in the right lines, the research department will help us to expedite it.

To conclude, I have touched on much that is elementary. I have done this because the general principles I have endeavoured to picture run through them. If we bear in mind that whatever we do is incomplete in itself and merely fits in as part of Nature's jig saw puzzle, we start with a sound foundation. Artificial manures have this effect through readjustment (chemically and physically) with the elements into which they are incorporated. Similarly, cultivation has its place in the scheme of things and the same applies to the use of green cover, organic matter, shade and protection, and my effort has been to emphasise the practical and economic factors that run through the basic principles of agriculture.

DISCUSSION AND CLOSE OF CONFERENCE.

THE CHAIRMAN remarked that they were all indebted to Mr. Megget for his address and he hoped that Mr. Megget's example in coming forward would be followed by others at their next conference. Before the meeting closed, he felt sure they would like to hear from their Acting Director of Agriculture.

DR. SMALL, responding to this invitation, said that he was glad of the opportunity of expressing the pleasure which the Department of Agriculture experienced in housing the first conference of the Institute. It was an honour which the Department highly appreciated. He also offered his congratulations on what was, in his opinion, an extremely successful initial conference. The only suggestion he had to make was that at future conferences of the sort, printed abstracts from the papers to be read should be handed round beforehand to those likely to attend the meeting in order that they would have a better idea of what was going to be discussed. He hoped the present conference was merely the forerunner of many more equally successful.

THE CHAIRMAN expressed the Institute's gratitude for the accommodation provided for them that day, for the Acting Director of Agriculture's personal attendance and for the attendance of his officers. They (the officers) had heard a lot and perhaps had learned a little. He could assure them that when they met again next year, he sincerely hoped that the co-operation and co-ordination which had begun in the last year to exist between the Department of Agriculture and the Tea Research Institute would have been further cemented. They were all very pleased that they had been able to hold the conference, and he sincerely hoped that this gathering would have the effect of stopping some of the "back chat" going on in several districts in the Island. The Institute had had an extremely difficult task to perform and it had many critics. Unfortunately most of these would not come out into the open. They would welcome criticism warmly if it was expressed openly and through the proper channels.

If the Tea Research Institute was given a chance, he was perfectly certain that it would not be found wanting in performing the work it has set out to do.

The Conference terminated with a vote of thanks to the Chairman.

REVIEW OF THE TEA RESEARCH INSTITUTE PROGRESS REPORTS.

The following review relates to the progress reports for the quarter terminating March 31, 1929.

In the last review reference was made to delayed recovery from collar pruning. In this connection Mr. S. R. Hamer writes that a tea bush collar pruned in March 1927 gave no sign of bud growth until April 1928, since when the recovery has been most satisfactory. The bush is now developing a fine frame. It is not generally known that collar pruned bushes may lie dormant for such long periods and that there is every possibility of recovery so long as the root system remains alive.

A dieback of tea branches has been prevalent in the Agrapatna, Lindula and Nanu Oya districts this year. The disease occurs in fields during the first year after pruning and is recognised by the presence of one or two branches with withered leaves in the bushes. The cause of the disease is unknown, but infection usually occurs at the base of the shoot where it is attached to the parent branch. The disease has previously been observed in the Agras when it disappeared with the advent of wet weather. This year the disease has again occurred during drought and it is to be expected that it will disappear with the arrival of rain. Diseased branches should be pruned out and burnt; the cut should be made on the parent branch below the point of attachment of the diseased shoot.

As the work on the "Witches' Broom" disease of tea has failed to reveal the presence of a causal pathogen, and the field evidence suggests that soil conditions may be a primary factor in the causation of the disease, the Agricultural Chemist has undertaken a preliminary survey of "Witches' Broom" soils. It appeared possible that the disease might be associated with definite soil reaction values but from a representative selection of Dimbula soils, no difference could be established between good and bad soils in regard to their reactions.

Further soil samples have been subjected to the 'single factor' determinations reported previously. At the request of the International Soil Science Society, the Institute has arranged to partake in the exchange of information on this subject. This exchange should enhance the work of the Institute in that the work will be co-ordinated with that of other workers on this subject throughout the world.

A start has been made in the study of the clay fraction of Ceylon soils. The investigations are being directed along three lines:—

(1) The physical nature of the soil as modified by the soil colloids.

(2) The chemical behaviour of the soil colloids as reflected in basic exchange phenomena.

(3) The chemical nature of the colloid complex itself.

The Biochemist returned from leave on March 4, 1929. While in England he was able to study the problems of air flow, temperature and humidity determinations and to select precision instruments for the elucidation of these problems as they apply to tea manufacture. Since his return he has been mainly occupied with the analyses of samples of made tea which had accumulated during his absence.

The Entomologist has continued his work on the breeding of the Tortrix egg parasite (*Trichogramma erosicornis*) and has carried out experiments in the propagation of the Wilt disease of Tortrix. The latter experiments, however, have not proved successful.

Further laboratory tests have been made with various proprietary and standard insecticides against such caterpillars as Nettle grub and Red slug. So far the most effective insecticides have proved to be Nitrolim and Pyrethrum. The latter has a great advantage in that it is a plant product which is innocuous to the plants on which it is used and has no toxic effect on birds of mamals.

Experiments with kerosene emulsions for the control of yellow mite have been continued. An emulsion prepared with flour appears to be more effective than one made with soap, but is more troublesome to prepare. Neither has proved very effective in the field without repeated applications. Experiments with tea have shown that an emulsion containing as much as 10 per cent. kerosene had no scorching effect even on the young and tender leaf though the tests were made in full sunshine. This is of interest because it is well known that kerosene emulsions tend to scorch the foliage of many plants, and it is rarely that emulsions containing more than 2 per cent. kerosene can be used without harm.

C. H. GADD.
Acting Director.

AIR CONDITIONING AND SOME OF THE PRINCIPLES INVOLVED.

D. I. EVANS.

INTRODUCTION.

At the present time, "air conditioning" or the adjustment of the temperature and the moisture content of the atmosphere, is becoming an established practice in the technique of tea manufacture. Advantage of the controllability of the atmospheric moisture is made use of to aid the wither on wet days, and to regulate the fermentation during very warm dry periods. When leaf is spread out to wither it is necessary that it should lose a certain amount of moisture to attain the proper physical condition suitable for rolling. This water lost from the leaf is taken up by the air which has the capacity of taking up water from moist surfaces exposed to it. The capacity of the air to take up moisture is variable according to the climatic conditions, which determine the amount of aqueous vapour present in the atmosphere. During wet weather when the air is saturated with aqueous vapour, it has no drying effect because it is not capable of taking up any further moisture, and it is when the air is approximating to this condition that the process of withering becomes difficult, or even impossible unless the leaf is allowed to lie on the racks for a prolonged period, or the air is made capable of taking up more water by artificial methods. Formerly, a wither was obtained by spreading the leaf so thinly that the water could evaporate naturally, and it was allowed to lie on the racks until the necessary loss of moisture was obtained. But, at present the increase in crop and the large quantity of leaf to be dealt with makes it necessary to clear the tats within a reasonable time so as to accommodate the next day's crop. Attempts were made to overcome this difficulty when the tat space was too small to deal with the crop by withering in the sun. But, withering in the sun has been found to be unsatisfactory as it is very difficult to get a uniform wither, and the leaf is liable to turn brown unless it is carefully watched. However, most factories today have sufficient tat space for their leaf, and the sun is not available during the wet periods so that some other method of withering is necessary. Nanninga describes a method of making the leaf supple by exposing the leaf to a very low temperature in refrigerators and then allowing the temperature to rise suddenly. The leaf is killed by this method and reduced soft and pliable, but the method is quite impracticable for several reasons which need not be discussed in this article.

A wither could be obtained in a partial vacuum, when evaporation is very rapid, but the installation necessary for dealing with a large crop would be too expensive for economic working.

The other method of withering, which is now a firmly established practice, is to use warm air of a certain degree of dryness. This is produced by mixing warm air with the outside air when that is too moist for withering purposes, and drawing or pushing the mixture over the leaf by means of powerful fans. The successful manipulation of the air mixture depends on a knowledge of the moisture content and temperature of the atmosphere, and since this requires at least a passing acquaintance with the principles of hygrometry, a section of physics which deals with atmospheric moisture, the present article explains the principles involved, their interpretation and the methods of measuring the amount of aqueous vapour in the atmosphere.

VAPOUR PRESSURE.

The atmosphere always contains a certain amount of aqueous vapour since moist surfaces are invariably exposed to it, and because liquids possess the property of evaporating into space and exerting their own pressure. This pressure is known as vapour pressure, and it can be measured in the same way as the atmospheric pressure is measured. If a long tube closed at one end is filled with mercury and then inverted so that the open end is below the level of a layer of mercury in a trough, the mercury column will fall if the tube is longer than 30 inches, but it will remain stationary at about 30 inches, leaving a vacuum in the tube above it. The column of mercury is then balanced as it were by the pressure of the air; the height of the column is a measure of the atmospheric pressure under the existing conditions and the apparatus becomes the ordinary barometer in general use. If a bubble of air is allowed to pass into the vacuum, the column of mercury is depressed, owing to the pressure exerted by the air admitted in the bubble. In a similar way if a small drop of liquid, such as water, is introduced the column will be depressed, and the liquid will disappear from the surface of the mercury column owing to evaporation. This evaporation takes place at ordinary temperature which is far below the boiling point of water, and it illustrates the tendency a liquid has of evaporating into space. When more drops of water are admitted a point will be eventually reached when the liquid remains floating on the surface of the mercury, no further evaporisation takes place, and the column of mercury is not depressed. The difference between the height of the column of mercury when it remains constant on adding another drop of water and the height before adding any water gives the pressure due to the water at that temperature. If the space above the mercury is increased, then, provided there is water present, a little more will vaporise, but the column of mercury will remain at the same height. If the space is decreased, a little water will condense to liquid although the height of the mercury column

above the surface of the mercury in the trough will remain the same. This means that in the presence of excess of water, the pressure exerted by the aqueous vapour remains constant, although on increasing the space more water will evaporate. If the temperature is raised then more water will evaporate and the column of mercury is again depressed, so that raising the temperature increases the vapour pressure. Lowering the temperature has the opposite effect. The vapour pressure of a liquid therefore depends on the temperature only, and is a direct measure of the quantity of liquid a given space will hold.

The above illustration refers to space which is free of other gases, but it has been shown by Dalton and Gay-Lussac that "The pressure exerted by, and the quantity of, a vapour which saturates a given space are the same for the same temperature, whether this space is filled by a gas or is a vacuum." As far as vapour is concerned, a space filled with air will behave as a vacuum, the only difference being that vaporisation of the liquid is very much quicker in a vacuum than in a space filled with air. The points to be borne in mind from the above are:—

(1) Every liquid exerts a definite vapour pressure which determines the amount of vapour that will fill any given space.

(2) The vapour pressure of a liquid, and the amount of its vapour any given space will contain will vary with the temperature only.

(3) The presence of any other gas in any given space has no effect on the vapour pressure of the liquid.

(4) Every liquid exposed to space will vaporise into the space until it exerts its maximum vapour pressure.

HUMIDITY OF THE ATMOSPHERE.

The atmosphere moving constantly over the surface of the earth is in contact with water surfaces such as the sea, lakes, rivers and transpiring vegetation, and, since as stated in the previous section water exerts a vapour pressure and therefore evaporates into space, the air invariably contains water vapour. The maximum amount of water which a given volume of air will contain at any time depends on the vapour pressure, which is controlled by temperature only. This is usually referred to as saturated air, and the weight of vapour present at saturation has been determined at various temperatures, and incorporated in the form of tables such as Glaisher's Hygrometric Tables. On referring to these tables, it will be seen that the weight

of vapour present in a cubic foot of air varies considerably with the temperature, and a few examples are given below to illustrate this:—

Weight of aqueous vapour in a cubic foot of saturated air at different temperatures.

° Fahr.	Grains of water in cubic foot of air.
10	0·8
15	1·1
20	1·3
30	2·0
40	2·9
50	4·1
60	5·8
70	8·0
80	11·0
100	19·8

In general, the air contains less water vapour than would saturate it, and because of this it is capable of taking up more water from any moist surfaces such as tea leaf when exposed to it. It then acts as a drying agent, and its capacity to dry any material depends on the amount of water it can take up before it becomes saturated. The quantity of vapour it can take up depends on the difference between the weight of aqueous vapour actually present, and the weight of aqueous vapour present when the maximum vapour pressure is exerted. If 'a' is the amount of water present in the air, and 'b' is the maximum amount of water it can take up at that temperature, then a/b is called the relative humidity, and 100 times this, or 100a/b is called the percentage relative humidity. When the percentage relative humidity at any temperature is known, it is easy to find how much moisture the air will take up on referring to the tables. Examples of this at 60°F are given below:—

Weight of water a cubic foot of air can take up at different percentage relative humidity, at 60°F.

Percentage Relative Humidity 100 a/b.	Grains of water in a cubic ft. a.	Grains of water in a cubic ft. when saturated b.	Grains of water a cubic ft. can take up (b—a).
100 ...	5·8 ...	5·8 ...	0
82 ...	4·7 ...	5·8 ...	1·1
71 ...	4·1 ...	5·8 ...	1·7
62 ...	3·6 ...	5·8 ...	2·2
50 ...	2·9 ...	5·8 ...	2·9
30 ...	1·4 ...	5·8 ...	4·4

When the percentage relative humidity is 100, the air is saturated with moisture and it is not capable of taking up more moisture; when it is 82 it can take up 1·1 grain of water per cubic foot; and 4·4 grains of water when the percentage relative humidity is 30.

The percentage relative humidity is therefore a direct measure of the drying capacity of the air at a certain temperature, but it cannot be compared directly with air of the same percentage relative humidity at any other temperature as will be seen from the following figures:—

Weight of water taken up by a cubic foot of air of the same percentage relative humidity at different temperatures.

Grains of water in a cubic ft. of air at 60°F and 100% relative humidity ...	5·745
do at 60°F and 70% ...	4·022
1 cubic foot of air can take up ...	1·723
Grains of water in a cubic ft. of air at 83°F and 100% relaive humidity ...	11·987
do do and 70% ...	8·391
1 cubic foot of air can take up ...	3·596
Grains of water in a cubic ft. of air at 90°F and 100% relative humidity ...	14·80
do do and 70% ...	10·30
1 cubic foot of air can take up ...	4·50

Although the percentage relative humidity of the air is a measure of the drying power of the air at any particular temperature, it varies according to the temperature, and the significance of this will be dealt with when the application of the principle is discussed.

MEASUREMENT OF HUMIDITY.

Since the drying capacity of the air depends on its percentage relative humidity, it is necessary to be able to determine its humidity. This can be done in several ways. Many of the methods, however, are not practicable for daily observations, or, are not sufficiently accurate. Instruments used for the measurement of the quantity of aqueous vapour in the atmosphere are called Hygrometers, and have generally been made of substances which possess great capacity for absorption, and undergo variation from that cause. An example of this is the hair hygrometer which varies in length according to the humidity.

The most convenient of all methods, and the one most generally used, however, is to observe the temperature of evaporation, and the difference between this and the air temperature, that is, the temperatures indicated by wet and dry thermometers. The origin of the wet and dry bulb hygrometer is not quite certain, but its simplicity has led to its adoption for most meteorological and industrial work,

although it is admitted that the instrument in its elementary form is not very accurate. Satisfactory results cannot be obtained in stagnant air, and a strong ventilation is absolutely necessary to accuracy.

The wet and dry hygrometer consists of two thermometers as nearly as possible identical. Their bulbs should be small to be sensitive, and their graduations, which should be tested with a standard thermometer, should be on their own stems. The bulb of the wet thermometer is covered with thin muslin and round the neck of the bulb and over the muslin is loosely twisted, or tied in a loose knot, a conducting thread of lamp wick or floss silk. The wick passes into a near vessel of water in such a way as to allow a length of wick of about 3 inches. The water vessel should be placed below, but a little to one side of the wet bulb, so that the temperature of this water does not affect the readings of the dry bulb.

The water reservoir should always be filled with rain or distilled water as salts in solution in the water change the vapour pressure of water, and also contaminate the muslin as the water evaporates from it. Before use, the wick should be washed in a solution of carbonate of soda, and pressed while hot under water throughout its length. The wick should be long enough to supply sufficient water to keep the muslin as moist as when the air is saturated with vapour. By increasing or decreasing the conducting thread, the supply of water can be increased or decreased.

It is very important to keep the muslin in good condition, as the water always leaves a small quantity of solid material in the mesh when it evaporates. This will sooner or later stiffen the muslin so that it does not readily take up water, and the muslin takes some time to become wet when dipped in water. Deterioration of the muslin is further accentuated in tea factories by the dust in the atmosphere, so that it is essential to renew the muslin from time to time. I have seen hygrometers, which were supposed to give results, when the muslin was caked with tea juice or dust. If more care than that is not taken of them it is not much use having a hygrometer at all as the results are quite untrustworthy. The hygrometer should be freely exposed to the atmosphere and never boxed in, as in that case a more saturated atmosphere will be formed in its immediate neighbourhood owing to evaporation from the muslin. When a hygrometer is used to determine the humidity of the rolling or fermenting room, it should never be placed immediately above the fermenting leaf because the evaporation of moisture from the leaf will affect the readings, and a low difference between the wet and dry bulb readings may only mean that moisture is evaporating from the leaf. This may appear an unnecessary warning, but unfortunately I have seen this actually done in practice.

The hygrometer depends on the principle that water takes up heat when it vaporises. In this way, if the wet bulb thermometer is exposed to an atmosphere capable of taking up water in the form of vapour, then water will evaporate from the surface of the muslin and the heat necessary for this is absorbed from the thermometer and its immediate neighbourhood so that the wet bulb thermometer is cooled. It will then register a lower temperature than the dry bulb thermometer which gives the temperature of the air. The difference between the two readings will depend on the amount of water evaporated from the muslin and this again is controlled by the degree of unsaturation of the atmosphere. The difference between the wet and dry bulb readings can therefore be used to determine the relative humidity of the atmosphere when properly determined.

Another form of hygrometer, which ensures a suitable movement of air across the wet bulb is the Sling or Whirled Hygrometer. This instrument consists of a pair of thermometers on a board provided with a handle, which allows the thermometers to be whirled rapidly so that the bulbs are quickly and efficiently affected by the temperature of, and moisture in, the air. The wet bulb thermometer which is covered with wet muslin is slightly lower than the dry bulb thermometer and it is thoroughly saturated with moisture before making an observation, by being dipped in water. In making an observation, the thermometers are whirled rapidly for 15 or 20 seconds; stopped; and quickly read, taking the wet bulb reading first. This is repeated until two successive readings of the wet bulb are found to agree closely. The Whirling Hygrometer is a most realiable instrument and is also comparatively cheap.

In reading either of the above hygrometers, the eye should be placed level with the top of the mercury in the tube; the observer should be careful to refrain from breathing when making the observation and the hygrometer should not be held in the hand at the bottom where the wet and dry bulbs are situated, otherwise the temperature of the body will affect the readings.

THE PART PLAYED BY ORGANIC MATTER IN SOILS.*

T. EDEN.

The formation of residues of organic matter in the mineral fragments which are the products of the weathering of rocks is one of the landmarks in the production of a cultivable soil. It is in fact the most important landmark, for only when such organic matter is present can the products of weathering rightly be called soil. By this accumulation, agricultural soil is distinguished on the one hand from sand, and on the other from weathering products such as china clay. Thus it is that to a unique degree the acceptable properties of an agricultural soil are connected with the reserves of organic matter which it contains. The following is an attempt to condense into the space of a single lecture an account of the ways and means by which organic matter exerts this preponderating influence.

Soil organic matter results from the decomposition of living plants grown in or on the surface of weathering mineral. Starting with primitive forms, such as the green algae which can be seen for example as a thin film on rocky surfaces, plant pots and the like, a more and more complex vegetation is developed as time goes on, until in some such climax as forest with abundant leaf fall, a definite layer rich in organic matter is attained. All soils contain organic matter in varying stages of decomposition, but agriculturally, it is the partially decomposed mass which is important, particularly that portion forming a dark, amorphous substance, usually referred to under the loosely conceived name of humus. Humus is what is termed a colloid. The name is derived from the Greek word for glue, and was first used to describe this type of substance because the earlier discovered colloids had the property of stickiness quite well developed. As our know ledge of this type of substance has increased, more definite methods of diagnosis have become known, but for soil colloids at least this property of stickiness is still a general one. It is the properties that humus has as a colloid which are responsible for one important aspect of humus as a beneficial substance in the soil. With this aspect, the effect of humus on the physical properties of the soil, I propose to deal first.

The importance of a good tilth in an agricultural soil is a point which there is no need to labour, although it is notoriously hard to define just what is meant by tilth. Soil in a good state of tilth works easily without being too open. It does not wash down and run in wet weather, nor bake and 'cap' in dry spells. It drains easily without

* Paper read before the Dolosbage and Yakdessa, P.A. May 15 1929.

parching; it does not become waterlogged. Now all these properties are affected to an enormous extent by the size of the particles of which the soil is made up and by the state of aggregation or packing in which they are found. This latter property is modified considerably by the presence of humus. In the first place, visualising humus as a jelly like substance which coats the surfaces of mineral particles, it is obvious how it tends to bind loose and sandy soils. With stiff clay soils, soils that is with a considerable quantity of very fine particles, the effect is the opposite. The very intimate incorporation of humus with the mineral particles makes for the association of these particles in groups or crumbs which are less tenacious than an aggregate of clay alone would be.

A further beneficial effect is traceable to the colloidal property of imbibing considerable quantities of water. This action is accompanied by swelling, and the reverse action by shrinking. Such processes, alternating one with another, cause ruptures in the aggregates of soil particles, so that the conglomerations of soil crumbs are constantly altering, allowing of adequate aeration and the formation of minute drainage channels. The forces exerted in rupture and shrinkage are very great indeed. The actual rotting of a piece of plant material has a similar effect in that the volume of the humus-transformed substance is less than the original organic matter and leaves an air and drainage channel.

From what has been said it is evident that one cannot separate tilth effects from the question of the moisture holding capacity of the soil. A soil well supplied with organic matter can hold more water than a similar soil without it. This refers to actual gross quantity, and in mineral soils such as have been considered, this is almost always an advantage. What is more it holds the water where it is wanted-in the upper layers of the soil. The idea of a mulch is a familiar one, and of the various forms of mulch, organic matter ranks high in efficiency. On stiff tenacious soils, where additional water might be regarded at first sight as a disadvantage, a very important effect occurs. Whilst increasing the water holding capacity, humus nevertheless raises the moisture content at which the soil becomes sticky. In other words mere increase in water holding capacity would be a disadvantage if the soil became sticky in so doing. But with an adequate supply of humus, the advent of this undesirable limit is postponed, and, coupled with a greater supply of available moisture, is the advantage of a more comprehensive range of moisture content under which the soil is workable. Two of the most striking examples of the effects we have so far been discussing are illusrated on the classical plots at Rothamsted.

Barnfield is the most tenacious field on the farm, and at mangold sowing in wet weather the soil runs and then cakes with consequent harmful effect on the young seedlings. The plot which has received

F.Y.M. since 1856 is spared these disadvantages, so that even in the early stages of growth the plants come away more quickly, and have a healthier appearance.

The corresponding plot on the Broadbalk permanent wheat field shows in its 85 year records much less fluctuation in yield than any other owing to the stabilishing effect of the organic matter on tilth condition and moisture content. Moreover the tile drain of this plot only flows after heavy rain. That drainage is adequate is shown by the state of the crop, but the organic matter in the soil can hold up the moisture without waterlogging, and a too rapid drainage is prevented.

A third aspect of the question is the effect of organic matter on the composition of the dilute solution in the soil from which the plant derives all its mineral food materials. There is an idea abroad that humus contributes largely and directly to the acidity of the soil, but this is a perversion of the actual case. Humus acts as a stabiliser in this case too, insomuch that it needs the release of a much greater quantity of acidic substance or withdrawal of a much greater quantity of basic material in a humus soil to alter the degree of acidity than in a soil not so supplied. In the current phraseology of soil science a humus soil is a well 'buffered' soil.

Then with regard to the actual nutrient elements in the soil, and more especially those which are added as manures, a soil devoid of colloid material would be absolutely incapable of retaining them under the continued influence of drainage. Colloids have the power of absorbing such important elements of nutrition as ammonia and potash. The explanation of the manner in which this is done must be reserved for another time, but the mere statement of the fact shows how important humus is for a soil in this particular respect. Incidentally, it is due to this absorbing effect on soil bases that it is possible to counteract undue acidity by the addition of lime.

So far, consideration has been entirely confined to the humus content of the soil *i. e.* organic matter which has reached a certain stage of decomposition. All the effects spoken of have been the result of those properties of humus which we have spoken of as colloidal. The actual processes of decomposition of raw organic matter are no less important for our consideration.

Whilst humus itself is not a nutritive substance as far as the higher plant is concerned, the products of the decomposition of organic matter represent the current account on which the plant draws for its supply of nitrogen. The action of bacteria and fungi in breaking down the complex substances of plant residues is a fact of everyday knowledge. The ammonia which is the final product of degradation is the starting point for other bacterial action whereby nitrates are

formed from which the plant can benefit directly. The prime cause of this decomposition of organic matter by soil organisms is their search for energy producing substances. Just as our human stores of energy are replenished by our assimilation of certain food stuffs, the so-called carbohydrates, (sugar, starch), so the micro-organisms obtain their energy by breaking down the carbon-containing matter of the soil. At the same time as they obtain the necessary energy, they require nitrogenous food as we do, and so some of the nitrates which have been formed as a by-product of other reactions are assimilated too, and revert in the bodies of the organisms to a form not immediately available to the plant.

There are, therefore, two opposing actions going on in the soil as a result of bacterial and fungal activity, one which breaks down to nitrate, and one which starting from nitrate builds up again. Eventually, the bacteria responsible for building up die and the breaking down starts again. The balance left by these processes is what goes to feed the crops and what is lost in drainage. If the building up process were absent, it is easy to see that in course of time all the nitrogen would become transformed into nitrates, and except for the crop's requirements, would be lost inevitably in drainage. Fortunately, as just indicated, a considerable portion of this is recapitalised.

The fact that when bacteria multiply as a result of an adequate supply of energy material, they lock up a definite quantity of nitrogen too, accounts for the fact that the ratio of the amount of carbon (energy material) to nitrogen in a soil is roughly constant, and has a value of about 10. This is an experimental fact of great importance, for, if a rich nitrogenous substance is added to a soil, what I have called the capital account is not benefitted unless a corresponding amount of carbon is added. On the other hand, if a rich carbonaceous substance is added, the bacteria will multiply and deplete the soil of nitrates in their attempt to provide adequate food for their multiplication. Such a thing occurs when unrotted straw is added to soils, a fact which was demonstrated many years ago at Rothamsted by the sudden decrease in crop when straw was ploughed in. Fortunately, this depletion of available nitrates is temporary, but is none the less serious.

The main point of the argument, however, is to show that whilst the continued supply of soluble artificials to a soil may at great expense supply enough nitrogen for immediate needs, the rest being lost in drainage, it does nothing to conserve nitrogen in the soil. Green manures on the other hand usually supply enough of both carbon and nitrogen to preserve the balance, and for that reason are of particular value. Experience in a variety of crops seems to show that a judicious use of soluble manures and organic matter does in fact give the best results. In this connection, manures like blood meal and castor cake

must be ranked as relatively readily available for their carbon content is much too small to conserve the large quantities of nitrogen they contain.

To sum up, organic matter in the soil is an excellent stabiliser, preventing large crop fluctuation by ensuring good tilth, stable moisture relationships, retention of valuable nutritive elements, and a conservation of the capital supply of nitrogen, the most expensive and most easily lost of all crop requirements.

SOIL ACIDITY AND BASE EXCHANGE.

T. EDEN.

A number of enquiries have been received concerning the definition of several of the terms in general use in soil science which have appeared in the annual reports and quarterly progress reports of the Institute. These have related especially to the so-called 'base exchange' and soil acidity, and since these two phenomena are closely related these subjects are dealt with here together, in the hope that they will interest others besides those whose enquiries we have received.

It will be necessary first of all to review a number of chemical terms and to link them up with soil usage. First and foremost of these terms is the term 'acid' and second in importance its counter-part 'base'.

The general properties of acids are well known. They are corrosive, readily dissolving metals; they are sour to the taste and they change the colour of certain dye stuffs such as litmus, the latter becoming red. To give a clear cut definition is difficult without indulging in chemical technicalities, but in a crude sort of way it may be said that the characteristic property of an acid is that it contains the element hydrogen, which can be replaced by metals and other allied substances. This replacement is what actually occurs when a metal is observed to dissolve in an acid, and the bubbles of gas evolved are of escaping hydrogen. Whilst this definition will serve it must not be taken as complete, since substances are known which have these properties but are not acids.

The properties of bases are opposed to those of acids. The more pronounced bases have a soapy feeling; they turn litmus blue, restoring the colour when reddened by acids. These strong bases or alkalis derive their name from the Arabic word for plant ash of which they form the major portion. In general, they are the products of the combination of metals with oxygen, and amongst the commonest are calcium oxide (burnt lime) and magnesium oxide (magnesia).

The most important property of acids and bases is their capability of combining together to give a class of substances which have no sourness or soapiness, and which do not cause litmus to change colour. Such compounds are called neutral salts, and include calcium carbonate, the common limestone of the agriculturist.

One further chemical definition must be made before turning to the question of soil acids and bases. The number of atoms of hydrogen that a molecule of an acid contains varies with the acid. Hydrochloric acid (spirits of salts) contains but one, and consequently when acted upon by a base, that atom of hydrogen is replaced and complete neutrality is attained. Other acids such as carbonic acid have two atoms of hydrogen per molecule, and in the process of reaction with a base, either one or both may be replaced according to circumstances. In the former case, the bicarbonate is formed; in the latter a neutral carbonate. To illustrate this we may take the combination of calcium oxide (lime) with carbonic acid, giving with one half of its hydrogen replaced, calcium bicarbonate, or, as it will be better to call it, calcium hydrogen carbonate; and with all the hydrogen replaced simple calcium carbonate. Since the hydrogen carbonate still contains replaceable hydrogen, it retains some of its acid properties. Such salts are termed acid salts.

Having thus cleared the ground we come to soil acids and bases. By far the greatest potential contribution to soil acidity is made by the so-called colloids which have been defined in the previous article. The colloidal portion of the soil includes the humus, and the finely divided clay particles. It is necessary to emphasize the word potential, because not only does the presence of colloid not necessarily imply acidity, but there is always the stabilizing factor of buffering to be reckoned with.

We have visualised an acid as being a molecule containing replaceable hydrogen, and we may visualise a crude soil colloid as being a weak acid made up of very large molecules with the hydrogen part located on the surface. Whereas simple acids contain few atoms of hydrogen per molecule, soil colloids contain very large numbers and consequently can form a very large range of acid salts as more and more hydrogen is replaced. The large surface which these particles present makes them capable of instantaneous chemical action.

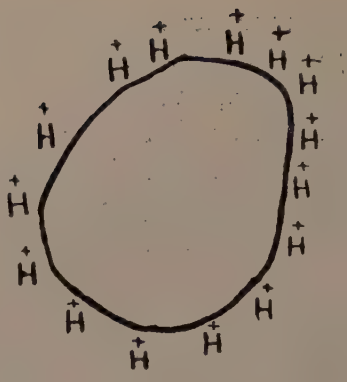


Figure 1.
Completely unsaturated (acid).

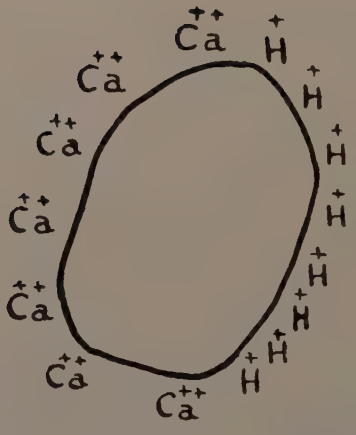


Figure 2.
Unsaturated (acid, neutral or alkaline).

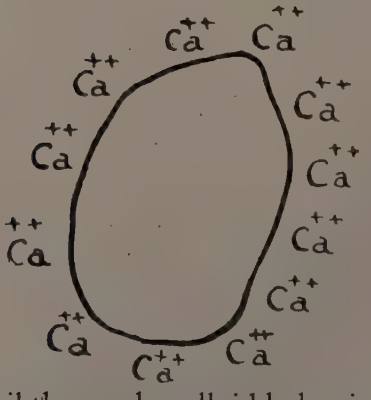


Figure 3.
Saturated (alkaline).

Now, in an agricultural soil the crude colloid behaving entirely as an acid, as in Fig, 1, is never found. Some of the hydrogen is always replaced by base as in Fig. 2. In other words the clay colloid particles behave as a hydrogen salt. It is equally rare to find the state depicted in Fig. 3 where all the hydrogen is replaced by base. We may, therefore, concentrate attention on the innumerable cases where both

hydrogen and base are present in various proportions, that is on examples where the soil is not completely 'unsaturated' with base as in Fig. 1, nor completely 'saturated' as in Fig. 3. Such soils may be acid, neutral or alkaline according as the proportion of base to hydrogen is small or large. What is perfectly definite is that if the proportion of base is increased the acidity is decreased, or the alkalinity enhanced, or vice versa.

Explanation will be rendered easier by actual examples. If lime is added to a soil similar to Fig. 2 some of the base will unite with the colloid and an equivalent amount of hydrogen will be replaced; in combination with the rest of the lime molecule this hydrogen forms water. It is now evident why we speak of basic exchange, because what has happened is merely an exchange in the colloid particles of one 'ion,' as it is called, for another—in this case calcium for hydrogen. The reverse case occurs when leaching takes place. Soil water always contains dissolved carbon dioxide, that is, it is a weak solution of an acid. Consequently, calcium is removed and is replaced by hydrogen.

But the addition of a base to a soil colloid not only pushes out hydrogen, it also displaces other bases. For instance, some soils, notably those which have been inundated by sea water, are saturated (using the term in the same sense as above) with sodium or nearly so. Such a soil is sticky and unfit for agricultural purposes. Thousands of acres of such land in Holland are being reclaimed by the addition of lime, which replaces the sodium by the process of basic exchange, and converts the 'sodium clay' into a 'calcium clay' which is friable and worakble from an agricultural point of view. It is a matter of common experience that the continued us of nitrate of soda in large doses on heavy land renders the soil sticky and liable to become poached. The appropriate explanation of this is that the sodium gradually and persistently replaces the other bases notably lime, forming that 'sodium clay' which has these objectionable properties.

When a base or salt is added to a soil not all of the basic portion is absorbed in this way by the soil colloid. Everything depends upon how closely into contact with the particle surface the added substances can get. It is thus not uncommon to find acid soils in which there is an abundance of free lime. In this case the large fragments of lime have had no opportunity to react with the colloids. For this reason the fine grinding of such substances and their thorough incorporation in the soil by adequate cultivation assumes great importance.

So far we have only dealt with the addition of bases. A similar action takes place when a neutral salt is added, with this distinction, that whereas a base can readily displace both other bases and hydrogen, the base of a neutral salt merely in the first instance replaces

another base. Small quantities of hydrogen may ultimately be displaced by secondary reactions.

We are now in a position to appreciate the part played by basic exchange in manurial practice. When sulphate of ammonia or sulphate of potash is added to the soil, the ammonia and potash portions take their place in the soil complex by a process of basic exchange and are held there. Such soluble substances would soon be lost otherwise in drainage. In this respect they have the advantage over nitrate of soda of which only the sodium is retained. This unfortunately is not the portion which is agriculturally valuable so that here in basic exchange we have an explanation of the more rapid loss of nitrogen in this form than in the case of sulphate of ammonia.

Finally, we can approach the question as to why sulphate of ammonia, a neutral salt, it termed a physiologically acid fertiliser. In the first place, the ammonium replaces the other bases but as it does so in equivalent proportions no immediate effect on acidity is caused. The sulphuric acid part combines with the displaced bases, and so there can be no question of its contribution to acidity. But when the ammonia is nitrified and is either used by the plant or lost in drainage, it will be seen that the soil has lost on balance an amount of base at least corresponding to the amount of ammonia added. It is this which brings about acidity, *i.e.* the ammonia part of ammonium sulphate which is responsible for the loss of other bases, and not the sulphuric acid part. Hence the term physiological acidity which is used in such a case.

ON A CATERPILLAR ATTACKING ALBIZZIA SEEDLINGS.

S. STUART LIGHT.

Macaria pluviata Fabr. is a Geometrid moth which (according to the Government Entomologist) has only been recorded once previously as a pest of cultivated plants in Ceylon. In June 1920 a few caterpillars, feeding on Albizzia, were collected from an estate in the Kotmale district, but the life-history was not determined.

Hampson, in the Fauna of British India, Moths, Vol. III, describes this species under the synonym of *Macaria sufflata*, Guén. (*M. horridaria* Moore), recording it from China, and throughout India, Ceylon and Burmah. The moth is evidently widely distributed in Ceylon, for the series at the Colombo Museum contains specimens from places as far apart as Colombo, Matale and Madulsima. Albizzia appears to be the only recorded food-plant.

The present record was made on an estate in the Maskeliya district, at an altitude of about 4,500 feet. About the middle of September (1928), two nurseries of Albizzia seedlings, situated half-a-mile apart, were found to be infested simultaneously by these caterpillars. In both nurseries a large proportion of the plants had already been destroyed by a leaf disease (*Phoma* sp.), and the survivors were much stunted and partly defoliated. The plants varied in height from $1\frac{1}{2}$ inches to 7 inches, with an average of 2 3 inches.

Nature of Damage.—The caterpillars fed in preference on the tender leaves, destroying the growing point and thus retarding the further growth of the plants. Many plants were completly stripped of their leaves. This was particularly the case with two beds at one end of the nursery, which were partly sheltered by young gum trees, and were therefore more heavily infested than the remaining beds; on one of the former, after a fortnight, the majority of the plants were reduced to mere skeletons of leaf stalks. Many of the plants were killed by the continued feeding of the insects, but others recovered ultimatively, although these were considerably set back.

When not actually feeding, the caterpillars assume the stick-like pose characteristic of this family of moths, usually taking up a position on the undersides of the leaf stalks, where the slender shape of their bodies and their peculiarly adapted colouring (described later) makes them difficult to "spot" without careful searching. On plants that had been completely stripped, the caterpillars often escaped detection, owing to thier actual resemblance (by reason of the lateral yellow stripe) to the bare leaf stalks themselves.

When the pest was first observed, fine weather prevailed, and while it lasted, from 10 to 30 caterpillars were taken from each bed every morning. Since the plants had been greatly depleted these figures are more significant than they appear.

No caterpillars were seen on Albizzia trees in the field.

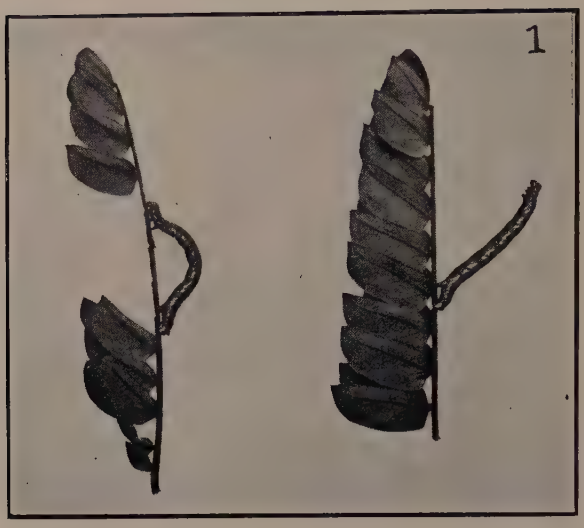
Control measures. Prolonged rainfall would always be a considerable check on the progress of this pest, feeding, as it does, exposed on nursery plants. But it is evident that it is very persistent, for even after a fortnight of continuous rainfall, caterpillars were taken from one of the end beds; and later, in November, when the weather had improved in the mornings, but heavy rainfall still occurred in the latter part of the day, caterpillars were again found on every bed.

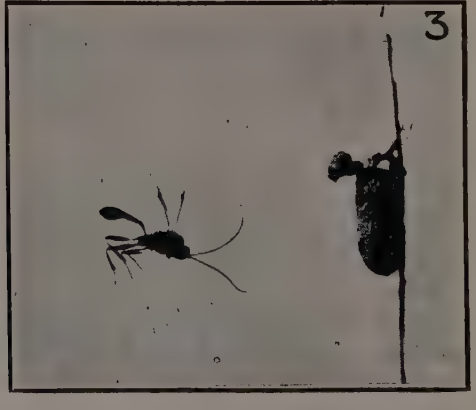
Spraying with Paris Green gave a fair degree of success, using this substance in the proportion of 1 lb. to 50 gallons of water. Two beds were sprayed on the first day, and three more on the day following. The results, calculated from the numbers of dead and living caterpillars found on the beds after 24 hours, showed a control of approximately 50 per cent. Unfortunately, almost continuous rainfall began in the afternoon of the first day, causing a decrease in the numbers of the caterpillars found on the beds on successive days. The results of spraying were therefore uncertain, but it is unlikely that the percentage of control was less than that stated above, for no dead caterpillars were, at any time, found on untreated beds.

Subsequently, further trials in the nursery not being feasible, owing to rainfall, the effect of Paris Green applied as a dust was tested in the laboratory. The poison was mixed with four times its weight of sifted lime, and dusted on with a muslin bag, shaken over Albizzia leaves which had previously been lightly sprayed with water. The caterpillars were then introduced to the leaves. Calculation of the results showed a control of 60% after one day and 90% after two days. Only one caterpillar died in the control cages, and this, it was afterwards discovered, was of a different species, introduced by mistake.

It was calculated that about $\frac{3}{4}$ to 1 gallon of spray mixture would be required to treat thoroughly one bed (6 sq. yards) of normally growing plants. Thus, in a nursery of 20 beds, such as one of those under discussion, 15-20 gallons would be expended, which, at the rate of 1 lb. to 50 gallons, require only 5 to 7 ozs. of Paris Green, costing little more than 75 cents to Re. 1, at the present price of this substance. For the process of dusting, even when the poison is diluted with lime, considerably more is required.

It is therefore recommended that, when many beds are to be treated, spraying with Paris Green, at the above rate, should be carried out,—to be repeated at intervals of a few days, until the pest shows signs of being effectually subdued. But if the outbreak occurs





1. Caterpillar of *Macaria pluviata* on Albizzia.
2. Moths and pupae.
3. Braconid wasp parasite and Cocoon.

in a small nursery or in a limited section of a large one, dusting with Paris Green, diluted with four or five times its weight of sifted lime, is advocated.

Life-History.—The caterpillar is about 25 m.m. long when full grown and is of varied colouring. The most frequent is grey, with very fine lines of darker grey running the whole length of the body above. Along each side is a rather broad yellow stripe, punctuated by a series of black spots. The first pair of sucker feet and the basal portion of the true legs are rose-red. In many the grey is replaced by green, and others are plum-coloured; in the latter the fine lines are frequently almost black. But in every case the colour of the feet and the yellow stripe remain unchanged.

The newly hatched caterpillar differs considerably from the older stages, its colour being dull olive-green with one broad yellow stripe almost covering the back. Individuals in the second and later instars (*i.e.*, periods elapsing between moults) were always found singly on plants. The length of the larval stage is between three and four weeks.

Pupation takes place in the soil; in the laboratory this occurred not more than an inch or so below the surface. Before emergence the pupa wriggles to the surface and remains with the forepart of the body projecting from the earth. The length of the pupa is 10-11 m.m., and the colour is a deep red brown, usually darkening to almost black over a great part of the body. The larvae were bred in well ventilated cages kept in an open verandah,—approximating closely to natural conditions. As they formed, the pupae were transferred to small wire-gauze cages for emergence. The pupal stage varied in length from 14 to 23 days, the average being $18\frac{1}{2}$ days.

The moth is of a lead grey colour on the upper surface of the wings, relieved by a triangular grey brown mark on the front margin of the forewing and a band of darker grey crossing both pairs of wings near the centre. On the reverse side, the colour is pale buff speckled with dark-brown, and crossed by several narrow bands of the same colour, which also spreads over the tip of the wing. The moths, confined in cages, lived 5-6 days without food.

The eggs are laid singly or in small clusters, mainly on the buds and youngest leaves, and owing to their colour, are not readily detected. The eggs are extremely beautiful,—bright emerald green when fresh, flattened oval in shape and crossed all over with a slightly raised network pattern. A few days before the caterpillars are due to appear, the eggs darken to a dull olive green, but all colour is lost after hatching, the shell being transparent and colourless. The egg-stage lasts 5—6 days.

Parasites.—A Braconid wasp is possibly an important parasite of the caterpillar. The adult wasp is about 5 m.m. in length, black, with a narrow yellow band on the abdomen, and yellow at the bases of the legs, which are themselves yellow brown in colour, the forelegs deepening to black in parts. The full-grown larva of the parasite, dull grey in colour and 7 m.m. in length, forms a most distinctive cocoon; this is about 5 m.m. long and 2 m.m. broad, cream coloured, with a ring of rather large black spots at either end, and two more bands of spots nearer the centre.

After being parasitised, the caterpillar evidently takes up a position near the tip of a bare leaf stalk, for the cocoons of the parasite were always found in this position, attached to the stem. The residue of the parasitised larva remains attached, with the head, on the outer side of the cocoon. From an examination of these larval heads it has been determined that only young caterpillars, probably of the second and third instars, are parasitised. Thus the older caterpillars are immune from attack.

Some idea of the part that the parasite is capable of playing in the control of this pest may be gained from the fact that on one day 90 caterpillars and 45 parasite cocoons were collected from the beds. The parasite emerges from the cocoon after 9-10 days and lives 3 or 4 days in captivity.

As with most parasites, this species is not without its hyperparasite, in the form of a black Chalcidid wasp, parasitic on the pupa.

A single pupa of Macaria was found lying on the surface of one of the beds, containing the puparium of a Tachinid parasite.

VITAMINS IN TEA.

It has been reported in the last few years that green tea is a good source of vitamin C, which is the name given to the accessory factor necessary in a diet to prevent scurvy. Very little is known of the antiscorbutic value of leaves as most of the work has been done on fruits and roots.

It is firmly established now that animals fed on a diet which is deficient in vitamin C develop scurvy, but will recover and become more or less normal again if this vitamin is introduced into the food in the form of fresh greens or any other source of vitamin C. This, of course, implies that the scurvy has not been allowed to develop too far.

There is no chemical method of testing vitamin C, so that the value of any substance as an antiscorbutic is determined by means of feeding experiments. Guinea pigs are fed with a vitamin C deficient diet such as whole oats, milk powder heated so as to destroy the vitamins, and specially prepared butter fat. The test can be carried out in one of two ways. First, the animals are allowed to develop scurvy by being fed with such a ration, and then determining whether they recover or not on adding the substance to be tested. If they recover, then it is concluded that the substances tested contain vitamin C; if not, that the substance is deficient in vitamin C. The other method is to feed the animals on this diet with the addition of a source of vitamin C, and then to keep one lot of animals on a diet containing vitamin C, and another lot on the vitamin C deficient diet plus the substance to be tested instead of the original source of vitamin. If the substance to be tested contains the vitamin, then the pigs will flourish and gain weight; if not, they will lose weight and develop symptoms of scurvy.

Biochemical investigation has demonstrated the presence in tea of Bios I and II, which are claimed to be necessary for the normal process of reproduction in yeasts. (1). Miss Eastcott has separated Bios I from tea dust and shown it to be identical with inactive inositol (2). Osborne and Mendel (3) failed to find any evidence of the presence of vitamin B in a decoction of tea, and at that time there was no reason to consider the vitamin factor as of any dietetic value.

Recently there has appeared in the *Tea and Coffee Trade Journal* (4) an account of some investigations into the antiscorbutic value of tea. In 1924, Miura drew attention to the presence of vitamin C in green tea, and at the suggestion of the Japan Tea Promotion Committee, Dr. Murlin of the medical school of the University of Rochester, N.Y., carried out a series of experiments to determine the antiscorbutic value of tea. The first method was employed in carrying out the experiments, that is, the animals were allowed to develop scurvy by being fed with a ration known to be deficient in vitamin C.

An infusion of tea was then added as a source of vitamin and its effect noted. Forty animals were used but twelve of these had to be left out because the scurvy was allowed to proceed too far before applying the curative method. Nine animals were given orange pekoe, seven were given oolong, and twelve were given pan fired or basket fired green tea. Although only one animal is registered as having been completely cured of scurvy, and that in the green tea section, they claimed that green tea contains vitamin C, and that 15 cc of a 2% infusion of green tea is not far from the equivalent of 1·5 cc of orange juice or 2 cc of lemon juice. Oolong was found to be less effective; and orange pekoe was judged to be of little value as an antiscorbutic. The difference in vitamin C content of the teas is ascribed as due to the difference in manufacture, the vitamin being destroyed in the fermented teas such as orange pekoe by oxidation during the process of tea making. This is suggested as parallel with the well known instances where vitamin C is destroyed by oxidation.

Of the nine animals supplied with an infusion of green tea, two died; two had severe scurvy, and five had mild scurvy at the end of the experiment, while two animals were discontinued owing to kidney trouble, leaving only one animal mentioned as having completely recovered. The lung and kidney trouble interfered greatly with the interpretation of the results so that their conclusions appear to be very inconclusive.

Green tea was then advertised as containing vitamin C, but Dr. Helen S. Mitchell of the Nutrition Laboratory, Battle Creek, Sanitarium Michigan, carried out feeding experiments with a high grade of green tea as the source of vitamin C, and failed to find any antiscorbutic value in green tea. In the first experiments carried out, it appeared as if an infusion of tea supplied some toxic factor which hastened the death from scurvy of the animals fed on vitamin C deficient diet.

Dr. Mitchell then undertook to repeat the tests with samples of green tea supplied by the Japanese Tea Committee. These samples represented the 1927 and 1928 crop, and the tests were carried out by the second method mentioned, that is, the 10 pigs used in the first experiment were fed on the scorbutic diet plus fresh greens for 25 days, and at the end of this period one was allowed to remain on scorbutic diet; one given an addition of fresh greens; four given an addition of 1927 and four given addition of 1928 tea; to the scorbutic diet. In the second experiment the preliminary period was 10 days, then 2 pigs were given the scorbutic diet; 2 received 1 and 2 c.c. of orange juice respectively and 12 received the 1927 and 1928 additions of tea, and a daily record was kept of the tea consumed.

Apart from the animals receiving greens or orange juice and one which was doubtful, all of them developed scurvy and showed a loss of weight. The animals receiving greens or orange juice showed complete protection from scurvy and a steady gain in body weight, and no lung or kidney trouble was encountered in these experiments, so that evidence of the toxic factor was not substantiated.

Dr. Mitchell concludes that these experiments do not show any demonstrable amount of vitamin C in green tea, and recommends commercial advertisers to verify the statements they make about green teas. Although it may be disconcerting to find that black tea has no antiscorbutic value, it is gratifying to know that fermented tea is no worse off in this respect than green tea.

(1) Wildier. Science 59. 197-9. 1924.
(2) Eastcott, E. V. J. Physical Chem. 1928, 32. 1094.
(3) Osborne and Mendel. Carnegie Institute of Washington. Yeear Book No. 377. 1922.
(4) Tea and Coffee Trade Journal Vol. 53, No. 5 November, 1927. 1257-1260 Vol. 56, No. 5 May, 1929. 756.—760.

D. I. EVANS.

REVIEW OF THE TEA RESEARCH INSTITUTE PROGRESS REPORTS.

The following review relates to the quarter ending June 30th 1929.

The further diminution of staff has militated against the progress of the research activities of the Institute. Arrangements have been made for dealing with the advisory work of both the mycological and entomological divisions.

Further progress has been made in the characterisation of Ceylon soils and a series of determinations of the silica-alumina ratio in the clay fractions has been commenced, but as these need constant attention their completion is delayed until the soil Chemist is relieved of administrative duties. The plucking of the Uniformity Trial and the analyses made in conjunction with each plucking have been maintained.

The Biochemist has completed up to the date the analyses of samples of made tea and tea leaf from the experimential plots which had accumulated during his absence. It was pointed out in the Annual Report for 1926 that the comparison of teas from different estates was likely to lead to conflicting results on comparing the analytical results with market valuation, but that there should be a closer connection between chemical composition and valuation of teas turned out by the estate over a period. This is borne out by the results of the investigation of the made teas, as there is a close parallelism between

the composition and the valuation of teas from any one estate. This parallelism is well brought out when the acid soluble tannin content is considered.

	% Acid soluble Tannin	Valuation in cents.
Estate A.	10·2	128
	11·6	166
	13·0	178
Estate B.	11·3	101
	12·3	113
	13·2	119
Estate C.	12·7	120
	13·4	133
	14·8	139

Although the valuation increased with the acid soluble tannin content on all estates, the tea from estate A appears to have a considerably higher value per unit of acid soluble tannin than estates B and C. There also appears to be greater uniformity for the higher priced teas than for the lower priced teas, but it is evident that the whole question of quality and composition is a complicated one and deserves careful if prolonged study.

The breeding of Trichogramma went forward fairly satisfactorily until the middle of June. At this time a daily average of nearly 2,000 parasites was being maintained. During the latter half of June a sudden decline in percentage parasitism and total number of emerged parasites set in. The reason for this is obscure, but is thought to be due to physiological causes, since at the same time a marked deterioration in the size and strength of the parasites was noticed. In spite of all attempts to stop this deterioration and to foster the parasites the strain became virtually extinct. Immediate steps were taken to replace this stock from egg masses collected in the various districts, but this attempt is hampered by the low degree of parasitism egg masses show at this time of the year. Applications for renewed stocks of Trichogramma have been made both to India and Java. The production of Sitotroga eggs has been put on a firmer foundation by ridding the maize bins of mites which prey upon Sitotroga eggs and larvae. Flowers of sulphur has been found to be specific against *Pediculoides ventricosus*, the mite concerned.

T. EDEN.

Acting Director.

NOTICES.

Advisory Work.—In order to ensure that specimens are dealt with expeditiously and arrive in a good fresh condition, Superintendents are asked to forward them, until further notice, to the following addresses:—

Mycological specimens.

Mr. M. Park, Department of Agriculture, Peradeniya.

Entomological specimens.

Mr. F. P. Jepson, Department of Agriculture, Peradeniya.

In order to avoid any possible confusion arising out of a number of specimens arriving by train from various estates, the senders are asked to signify the place of origin on the address label.

Visitors Day.—The suggestion has been made that one day a month should be set aside as Visitors' Day to enable Superintendents and others connected with the Tea Industry in Ceylon to visit St. Coombs. This will be arranged as soon as the Factory is completed and the necessary improvements to the cart road with provision for parking cars have been made.

T. EDEN.

Acting Director.

AIR CONDITIONING AND SOME OF THE PRINCIPLES INVOLVED.—*(Contd.)*

D. I. EVANS.

INTERPRETATION OF THE HYGROMETER READINGS.

When the hygrometer readings have been carefully taken as described in the previous article (1) the degree of saturation of the atmosphere can be determined by reference to hygrometric tables of the type given below. Although it is not necessary to make continual references to the tables in ordinary practice, a complete understanding of the principles of air conditioning cannot be realised without their help. The second column of the table gives the weight of aqueous vapour present in a 1000 cubic feet of air when it is saturated at various temperatures between 50°F. and 90°F., *i.e.*, the moisture present when the relative humidity is 100. The next columns give the percentage relative humidity of air, the dry bulb reading of which corresponds to that in column I and of which the wet bulb reading is 1, 2, 3, etc., degrees lower than that of the dry bulb.

Suppose we take a concrete example, such as actual readings taken on an estate in Ceylon, to illustrate the use of the table and the information to be derived from the readings of the wet and dry bulb thermometers exposed to the air.

Temperature of the dry bulb thermometer	64°F.
,, ,, wet ,, ,,	62°F.
Hygrometric Difference	2°F.

On referring to the table, it will be found that when the dry bulb temperature is 64°F. and the hygrometric difference is 2°F., the relative humidity is 89%, and column II shows that 1000 cubic feet of air will contain 0·94 lb. of water vapour when saturated at 64°F. By simple arithmetic, the weight of moisture present in the air can be calculated, because it will contain $\frac{89}{100} \times 0{\cdot}94 = 0{\cdot}79$ lb. of aqueous vapour per 1000 cubic feet. This air can therefore take up $0{\cdot}94 - 0{\cdot}79 = 0{\cdot}15$ lb. of water per 1000 cubic feet before it is saturated. Although this air is capable of taking up 0·15 lb. of water per 1000 cubic feet, in actual practice it is found to be too humid for the proper withering of tea, and it then becomes necessary to change its humidity by artificial means.

AIR CONDITIONING.

It has been accepted in general that air which shows a hygrometric difference of about 7°F. is well suited for withering purposes. and when the hygrometric difference falls much below this withering is slow unless the air is conditioned in some way so as to ~~increase~~ decrease its

humidity. It has already been pointed out (I) that the vapour pressure of any liquid and the amount of its vapour any given space will contain, will vary with the temperature only, so that by simply changing the temperature of the air we can change its capacity of taking up moisture. If the temperature of the air used in the above illustration is lowered to 58°F., then, according to the table, it will contain more vapour than air at this temperature can hold, and deposition of moisture will take place until 1000 cubic feet of the air will contain 0·765 lb. of water. This is what happens when dew is deposited during cold nights, because the temperature of the air at the surface of the earth is lowered below the saturation temperature.

If the temperature of the air is raised, then the capacity of the air to take up moisture is increased. If the air is heated until its temperature is 70°F., it will be seen from the table that 1000 cubic feet of air can now hold 1·14 lb. of water vapour when saturated, and if it previously contained 0·79 lb. of water per 1000 cubic feet it can take up $1·14 - 0·79 = 0·350$ lb. per 1000 cubic feet, or $0·350 - 0·150 = 0·40$ lb. more than it did before it was warmed. The air has lost none of its moisture, but, by raising its temperature, its capacity to take up moisture has been increased so that it is now more efficient as a drying agent. The temperature of the wet bulb thermometer in this conditioned air would be between 63°F. and 64°F., and a wet body freely exposed to this atmosphere would be at this temperature and not at the higher temperature indicated by the dry bulb. This is an important point to bear in mind when discussing the effect of warm air on the withering leaf. Under proper conditions, the temperature at which the leaf loses moisture need not be materially increased by raising the temperature of the air so as to increase its capacity to take up moisture.

The warm air used for withering is generally heated in one or other of the following ways, both of which involve admixture of outside air with a quantity of hot air.

(a) A portion of the outside air is passed through a heater (dryer) and mixed with the cold outside air.

(b) The hot air coming from a dryer in operation may be used for mixing with the outside air.

(A) WARM AIR NOT USED FOR TEA DRYING BEFORE ADMIXTURE.

The temperature of the resulting mixture will depend on the temperature of the hot and cold air before they are mixed and the proportion in which they are mixed together. Suppose 3,000 cubic feet of the outside air is mixed with 1,000 cubic feet of hot air which has a temperature of 120°F., then the temperature of the mixture $= \frac{98 + (3 \times 64)}{4} = 78°F.$

If the hot air has not been used for drying tea then this mixture will contain the same quantity of moisture per 1,000 cubic feet as the unconditioned air.

On referring to the humidity table it will be seen that air at a temperature of 78°F. can hold 1·47 lb of water per 1000 cubic feet. Since the mixed air contains 0·79 lb. of water in a 1000 cubic feet, its relative humidity will be $\frac{0{\cdot}79 \times 100}{1{\cdot}47} = 54\%$, which according to the table corresponds to a hygrometric difference of about 10°F. This air would be considered too dry for withering purposes, but could be corrected by either mixing the warm air with more cold air, or by lowering the temperature of the hot air. Suppose it was mixed with six times its own volume of cold air, the temperature of mixture would be $\frac{120 + (6 \times 64)}{7} = 72°\text{F.}$, but the moisture in the air would be the same as before, *i.e.*, 0·79 lb. per 1000 cubic feet. The relative humidity of the mixture would be $\frac{0{\cdot}79 \times 100}{1{\cdot}215} = 65\%$, and the wet bulb temperature would be 65°F.

I Dry Bulb. Readings. °Fahr.	II Weight of 1,000 c. ft. of vapour lb.	Difference between wet and dry bulbs. °Fahr.									
		1	2	3	4	5	6	7	8	9	10
50	·58	93	86	78	72	65	58	51	45	38	32
51	·60	93	86	78	72	65	58	51	45	38	34
52	·63	93	86	79	73	66	60	53	47	41	35
53	·65	93	86	80	73	67	60	54	48	42	36
54	·67	93	87	80	74	67	61	55	49	43	37
55	·69	93	87	80	74	68	62	56	50	44	39
56	·72	93	87	81	75	69	63	57	51	45	40
57	·74	94	87	81	75	69	63	58	52	46	41
58	·765	94	88	81	76	70	64	58	53	47	42
59	·795	94	88	82	76	70	65	59	54	48	43
60	·820	94	88	82	76	71	65	60	54	49	44
61	·850	94	88	82	77	71	66	61	55	50	45
62	·875	94	88	83	77	72	66	61	56	51	46
63	·905	94	89	83	78	72	67	62	57	52	47
64	·940	94	89	83	78	73	67	62	57	53	48
65	·970	94	89	84	78	73	68	63	58	53	49
66	1·000	94	89	84	79	73	68	64	59	54	49
67	1·030	95	89	84	79	74	69	64	59	55	50
68	1·090	95	89	84	79	74	69	65	60	55	51
69	1·110	95	90	85	80	75	70	65	61	56	52
70	1·140	95	90	85	80	75	70	66	61	57	52
71	1·175	95	90	85	80	75	71	66	62	57	53
72	1·215	95	90	85	80	76	71	67	62	58	54
73	1·252	95	90	85	81	76	72	67	63	59	54
74	1·290	95	90	86	81	76	72	68	63	59	55
75	1·330	95	90	86	81	77	72	68	64	60	56
76	1·380	95	90	86	81	77	73	68	64	60	56
77	1·430	95	91	86	82	77	73	69	65	61	57
78	1·470	95	91	86	82	78	73	69	65	61	57
79	1·515	95	91	86	82	78	74	70	66	62	58
80	1·560	95	91	87	82	78	74	70	66	62	58
81	1·610	95	91	87	83	78	74	70	67	63	59
82	1·670	96	91	87	83	79	75	71	67	63	59
83	1·710	96	91	87	83	79	75	71	67	64	60
84	1·770	96	91	87	83	79	75	71	68	64	60
85	1·820	96	91	87	83	79	76	72	68	64	61
86	1·880	96	92	88	84	80	76	72	68	65	61
87	1·930	96	92	88	84	80	76	72	69	65	62
88	2·000	96	92	88	84	80	76	73	69	66	62
89	2·050	96	92	88	84	80	77	73	69	66	63
90	2·120	96	92	88	84	80	77	73	70	66	63

If the volume of cold air drawn into the factory by the fans is limited to three times the volume of hot air available, then the temperature of the hot air should not be so high if a mixture having a relative humidity of 65-70% is to be obtained. The temperature of the hot air should then be 96°F. when it is mixed with the cold air. This will give a mixture, the temperature of which is $\frac{96 + (3 \times 64)}{4}$ = 72°F. The relative humidity of this mixture will be the same as that of the air mixture obtained by mixing the hotter air with a greater volume of cold air.

(B) EXHAUST AIR FROM DRYER USED.

When the hot air has been used for drying tea before it is mixed with the cold air it will contain more water per 1000 cubic feet than the cold outside air because of the moisture it takes up from the drying leaf. There are no exact figures of the amount of moisture taken up by the hot air in passing over the moist tea in a dryer and this will vary with the degree of wither, rate and temperature of drying. But suppose we take as an illustration a pressure dryer with a 35'' centrifugal fan working at 360 revolutions per minute. Such a machine can evaporate 700 lb. of moisture per hour, or $\frac{700}{60}$ = 11·66 lb. of moisture per minute and uses 18,760 cubic feet of air in doing so. 1,000 cubic feet of air will therefore absorb $\frac{11{\cdot}7 \times 1000}{18{,}760}$ = 0·625 lb. of water from the drying leaf. The air already had 0·79 lb. of water before it entered the dryer so that on passing from the dryer it will contain (0·63 + 0·79) = 1·42 lb. of water per 1,000 cubic feet, so that on mixing this air with three times its own volume of cold air the moisture content of the mixture will be $\frac{(3 \times 0{\cdot}79) + 1{\cdot}42}{4}$ = 0·95 lb. per 1000 cubic feet, and if its temperature at the time of mixing is 120°F., the temperature of the mixture will be $\frac{120 + (3 \times 64)}{4}$ = 78°F. The relative humidity of this mixture will be $\frac{0{\cdot}95 \times 100}{1{\cdot}47}$ = 65%, and the wet bulb temperature will be 70°F.

The properties of the various air mixtures described are tabulated below:—

Comparison of Air Mixtures Obtained.

Physical Properties, etc.	Outside Atmosphere	Air Mixtures		
		Warm air passed over drying tea.		Warm air not used for drying tea.
		(1)	(2)	(3)
Temperature of Warm Air used °F		96	120	120
Ratio—Ordinary Air to Warm Air		3:1	3:1	3:1
Dry Bulb Temperature °F.	64	72	78	78
Wet Bulb Temperature °F.	62	65	67	70
Hygrometric Difference	2	7	11	8
Relative Humidity	89	65	54	65
Moisture in 1,000 cubic feet air when saturated (lb).	0·94	1·21	1·47	1·47
Moisture in 1,000 cubic feet air mixture (lb).	0·79	0·79	0·79	0·95
Lb. of Water 1,000 cubic feet of air mixture can take up before it is saturated.	0·15	0·42	0·68	0·52
Rise of Wet Bulb Temperature due to treatment.	—	8	5	8

It will be seen from the table of air mixtures that:—

(1) The conditioned air can take up 0·42 and 0·52 lb. of water per 1,000 cubic feet before it is saturated, whereas the unconditioned air can only take up 0·15 lb. of water per 1000 cubic feet before it is saturated.

(2) The rise in dry bulb temperature due to admixture with warm air is 8°F. and 14°F., respectively, while the increase in wet bulb temperature is 3°, 5°, and 8°F. This corresponds with a mixture obtained when the outside air is nearly saturated, so that the rise in temperature should not be much greater than this at any time, if the mixing is properly carried out.

(3) The disadvantage of using the exhaust air from the dryers when drying tea is that the resulting mixture will be 3°-4°F. higher than if the air had not been used for drying tea. This difference is hardly sufficient to offset the economy effected by making use of the exhaust air.

(4) Since the withering lofts become a closed circuit to all intents and purposes when using warm air, and circulation of air depends on the fans, it will be observed that the capacity of the loft fans is determined by the volume of warm air available from the dryers. The loft fans must therefore be able to draw in two to three times as much cold air as the dryer fans to obtain the maximum economy of hot air.

(5) Air mixture No. 1 has the same relative humidity as air mixture No. 3, but the latter can take up 0·10 lb. more water per 1,000 cubic feet before it is saturated because it is at a higher temperature. The hygrometric difference of the two mixtures is 7 and 8 but if the hot air were mixed with a little more cold air to get a hygrometric difference of 7°F., the two mixtures would be very similar in drying power.

Although the temperature of an air mixture only depends on the temperature and proportion in which the cold and warm air are mixed, the relative humidity of the mixture will depend on the final temperature of the mixture as well as on the proportion in which the cold and warm air are mixed, and also on the amount of water vapour present in the cold and warm air before mixing. When the temperature, relative humidity and proportion of cold air to hot air are known, it is possible to calculate the temperature, relative humidity and drying capacity of the resulting mixture.

AIR MIXTURES OBTAINED IN PRACTICE.

It is found in actual practice that the theory outlined above agrees fairly closely with the facts, and that the conditioned air follows the humidity and temperature changes predicted. A few specimens of air mixtures obtained in a Ceylon factory are appended

	Temperature		Moisture per 1,000 cubic feet air can take up.	Increase of temperature over outside air.	
	Wet °F	Dry °F		Wet Bulb °F	Dry Bulb °F
(1)					
Outside Air	68	71	0·175	—	—
Conditioned Air	74	82	0·550	6	11
(2)					
Outside Air	69	72	0·185	—	—
Conditioned Air	76	84	0·570	7	12
(3)					
Outside Air	71	75	0·250	—	—
Conditioned Air	78	86·5	0·630	7	11·5

It is generally accepted that air which shows a hygrometric difference of 7°F. is suitable for withering, but it must be pointed out that this difference does not represent air of constant drying capacity since this will vary with the temperature. Thus a difference of 7°F. at 56°F. represents air which can take up 0·31 lb. of water per 1000 cubic feet, while at 86°F. it will represent air capable of taking up 0·53 lb. of water per 1,000 cubic feet. A slightly lower hygrometric difference may therefore serve at lower elevations where the temperatures are high.

It should be borne in mind that the temperature of the atmosphere fluctuates during the day, and that the lowest temperatures occur during the night and in the early morning. If advantage is taken of these lower temperatures, it is possible to carry out an artificial wither with warm air at a lower temperature than would be possible under natural conditions in the middle of the day. The relative humidity of the air also varies with the temperature, and, unless rain is actually falling, the hotter periods of the day are also the driest, which is another reason against using warm air during the hotter periods of the day as far as possible. On the other hand the relative humidity of the air may be fairly low, but there is no air movement; the wither will be slow under such conditions unless the fans are used to cause the appropriate air movement.

AIR CONDITIONING FOR FERMENTATION.

When the leaf is rolled fermentation sets in, and the modern tendency is to treat the rolling of the leaf and the attendant operations as part and parcel of the fermentation. Separate fermenting

rooms are being done away with, and this requires that the conditions in the rolling room be controlled and adjusted as carefully as used to be done in the fermenting room. Fermentation is accompanied by a rise of temperature in the leaf, and if the rolling room atmosphere is dry, there is a tendency for the leaf to dry out during the roll breaking and when put out to ferment, which results in uneven infused leaf. The conditions to be observed in the rolling room are cleanliness, a cool, humid atmosphere, and a gentle circulation of air, so that the room is well ventilated without the creation of vigorous draughts. The last condition appears to be as important as any, but if the air is dry, that is its relative humidity is low, it accentuates the tendency to dry the fermenting leaf, and it becomes necessary to increase the humidity of the atmosphere, so that its relative humidity is almost 90-95 per cent.

The humidity of the air in the rolling room can be increased by a reversal of the process employed in conditioning air for withering, *i.e.*, by cooling the air as it enters the rolling room, but it is generally found simpler to increase the humidity by the introduction of water vapour into the air. The dry air is allowed to take up water by being passed through a column of water or a fine spray of water, or else a fine spray of water is pumped under pressure into the room itself when the dry air vaporises the moisture with the formation of a more saturated atmosphere. Whichever method is adopted results in cooling the room, the amount of cooling depending on the degree of unsaturation of the air and the final state of saturation of the air. Heat is necessary to convert liquid water into vapour, so that any water converted into vapour represents so much heat loss. The heat given up to the water is obtained from the air itself, and the temperature of the air falls as it becomes saturated. There is a limit, however, to the cooling effect since no vaporisation can take place when the wet bulb and the dry bulb temperatures are the same. The limit of cooling possible is therefore set by the wet bulb temperature, and humidification of the air of the rolling and fermenting room results in a more even fermentation at a cooler temperature. Methods of humidifying the air in the rolling room will not be dealt with in the present article, but I hope to return to that on another occasion.

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(1) Evans, D. I. Air conditioning and some of the principles involved. *Tea Quarterly*, 1929, *II*, 95.

APPLICATION TO THE EMPIRE MARKETING BOARD.

The Board of the Tea Research Institute has recently submitted to the Empire Marketing Board an application for a financial grant to cover (A) the installation of small-scale experimental machinery in the St. Coombs Factory and (B) the appointment of an Entomologist to make a detailed study of the parasites of insect pests in Ceylon. As the memorandum forwarded in support of this application summarises in a convenient form the present activities of the Institute and indicates some of the directions in which development is contemplated, it may perhaps be of general interest and is therefore published below.

MEMORANDUM TO THE EMPIRE MARKETING BOARD.

The Tea Research Institute of Ceylon was founded in October, 1925. Owing to difficulties encountered in securing a suitable estate, work has so far, however, been carried out in temporary quarters, and this handicap has naturally placed a severe limitation on the scope of the investigations it has been possible to undertake. In the present year, however, an estate of some 420 acres has been purchased at St. Coombs, Talawakelle, and plans passed for a well-designed laboratory and a modern factory giving facilities both for commercial manufacture and for experimental manufacture under precise scientific control. These buildings, together with quarters for the scientific staff, will be available early in the coming year, and the facilities thus provided will render possible a considerable expansion in the work of the Institute, both in the laboratory and in the field.

The capital expenditure involved has been met by means of a loan of Rs. 1,000,000 from the Ceylon Government, repayable by annual instalments extending over twenty-five years. The Institute, however, receives no grant from the Ceylon Government or any other source, and is dependent for its annual expenditure on the proceeds of a Cess of ten cents per hundred pounds on all tea exported from Ceylon, this sum being collected by Government. The Institute is, in other words, entirely maintained by the tea industry.

The scientific staff at present consists of a Director, Mycologist, an Entomologist and two Chemists, one in charge of soil investigations and field experiments, and one directing the biochemical study of the tea leaf and tea manufacture. A Plant Physiologist has also recently been appointed, but will not actually join the Staff until the beginning of the coming year.

Three Ceylonese Assistants have so far been appointed. Accommodation in the temporary laboratory does not permit of any further increase in numbers, but as soon as a move is made into the permanent buildings, a considerable expansion in subordinate staff will be necessary.

The present staff is qualified to undertake investigations in all the major branches of research as applied to the tea industry. In view of the limitations up till now imposed by lack of numbers and laboratory accommodation, particular stress has been laid on the accumulation of fundamental data. It is believed that results valuable from this point of view have already been obtained which will enable the expansion of work which will follow the move to the new experimental station to proceed on sound lines. Hand in hand with such work an extensive system of advisory work on estates has grown up. By means of the intercourse thus established between the research staff and the planting community, the Institute is kept closely in touch with practical problems, and the results of research are made available to the industry without delay. This process is further assisted by the publication of an Annual Report and a Quarterly Journal. In the latter a special feature is made of critical reviews of current work by foreign investigators in tea, thereby bringing to the notice of the planting community results which, by reason of language difficulties, have not hitherto been generally available. By means of the Institute's publications, which aim at giving the completest presentation of data possible, the Institute's work is rendered available to Empire tea-growers as a whole, and is not restricted to a local circulation.

The general lines of the work actually in progress are indicated in the summary given below.

SOILS, MANURES AND GENERAL HUSBANDRY.

The work is in its infancy at present. The most modern aspects of soil investigation are being brought to bear upon the properties of Ceylon soils, both from a generic and an agricultural point of view. Particular attention is being paid to the fundamental physical properties of the soil, its degree of laterisation, following the work of Martin and Doyne, and the inter-relationships between soil type, basic exchange, and soil reaction. Already, certain fundamental differences between average tea soils and other tropical soils are beginning to emerge. Special attention is being paid to the nitrogen and carbon cycles in the soil, since the retention of both these elements in the soil is so intimately connected, and plays so important a part in the healthy nutrition of tropical crops.

Soil investigations are kept closely in touch with field investigations, and field experiments are planned to fit in with the laboratory studies of liming, uptake of soil nutrients, and the carbon-nitrogen

cycles. The field experiments are accorded a position of primary importance. When the work of the Institute was started, it was discovered that little attention had been given elsewhere to the question of experimental technique and design of tea experiments. Work is accordingly now in progress on this important aspect. Full advantage is being taken of the most recent advances in plot technique which allow of a strict statistical control of the results and their attendant errors. From a uniformity trial now proceeding, fundamental data regarding plot size, shape and arrangements are being collected, which will ensure that the Institute's experiments will conform to the standards of accuracy necessary for the production of sound and incontrovertible conclusions. Such fundamental studies have a general application outside Ceylon.

THE CHEMISTRY OF THE TEA LEAF AND MANUFACTURING PROCESSES.

A detailed study is being made of the composition of the fresh leaf. By means of improved methods of analysis worked out in these laboratories, the variation in the composition of the leaf from plucking to plucking and at different times of day, over a pruning cycle, is being followed. In this way, the seasonal and pruning cycle variations are obtained. In addition to the compounds generally held to influence quality in tea, the uptake of mineral nutrients is being followed. The rate of uptake of these latter has important bearings on manurial practice.

A comprehensive programme of research on the changes accompanying tea manufacture is in hand, but until the experimental factory is complete in a few months' time, this work has to be restricted to the first process, that of withering. On a continuous series of plucking samples, the effects of under and over-withering have been followed, as well as the changes taking place under normal conditions. The supreme importance of this process has been demonstrated. Correlated with the work on the fresh leaf is work on the seasonal variation of made tea from a representative number of estates at varying altitudes and on varying soils. Promising correlations between composition and quality, as reflected in market valuation, are being further investigated.

The completion of the factory will make possible a more complete study of the withering and subsequent process of rolling, fermentation and drying. The factory design allows of testing the value of varying engineering processes for the production of optimum conditions of ventilation, humidity, etc., and for the keeping of detailed meteorological records.

It is also proposed to instal small-scale experimental machinery, rollers, dryers, etc., in the factory. This will render possible the

manufacture of tea from small quantities of leaf from the experimental plots and allow of comparisons being made between different treatments.

Such experiments should give results of the greatest value as the work can be carried out under strict scientific control, leaf from different plots being treated simultaneously. The expense in installing such experimental machinery will, however, be heavy as no such plant is available at the present time, and the machines will have to be specially designed. Cognate researches on barley and malt, wheat milling, tobacco, etc. have, however, shown the great value of this type of work, and there is not the slightest doubt that the results obtained would fully justify the expenditure necessary.

As information thus gained would be available to the tea industry generally, it is suggested that this is a direction in which the assistance of the Empire Marketing Board might well be invited, a grant of £1,000-0-0 for experimental machinery being asked for.

PLANT PATHOLOGY AND PHYSIOLOGY.

In addition to original work on the fungus and insect diseases of tea, much advisory work on these problems is carried out by the officers concerned, and the assistance of the Institute in dealing with such attacks is being increasingly sought.

Modern work on these diseases, both here and elsewhere, indicates that investigations on such subjects must take into account not only the pest concerned and methods for its elimination or reduction but also a study of variations in the tea plant itself which render it more or less liable to such attacks. Climatic and soil conditions, manurial treatment, methods of cultivation and pruning, etc., are all factors which will influence the vigour of the plant, the composition of its individual parts, including the leaf and its resistance to unfavourable conditions. Variations in the constitution of the leaf moreover involve variations in the quality of the manufactured tea, and further knowledge of the factors controlling such differences is most desirable. A systematic physiological study of the tea plant, both from a botanical and biochemical standpoint, is therefore of the highest importance and will be undertaken as soon as the officer appointed arrives in Nuwara Eliya.

From the entomological point of view much importance attaches to further study of the biological control of insect pests by the introduction of suitable predators parasitic to the insect concerned.

Some work, under rather unfavourable conditions, has already been carried out by the Institute's staff on the control of Tea Tortrix by such a method, efforts being made to multiply an indigenous parasite, *Trichogramma*. Such an indigenous parasite is, however, likely to be already in ecological equilibrium with its host. It is

clear that an investigation of much wider scope is urgently required to investigate generally the biological control of insect pests of tea and other crops in Ceylon on similar lines to the work now being carried out in the West Indies. The Institute's Entomologist, however, will not have time for his more specialised investigations and advisory work and also for a general investigation of the type suggested. As the latter enquiry would be of general interest not only in Ceylon but also to other countries and to other industries than tea, it seems reasonable to suggest that a grant should be sought from the Empire Marketing Board for this purpose. In the case of the West Indies a sum of £2,000-0-0 a year for three years was allowed, and a similar sum is asked for now.

To sum up it is believed that the scope of the work in progress or contemplated by the Tea Research Institute, maintained as it is entirely by the tea industry, justifies an application to the Empire Marketing Board for assistance. A consideration of the various problems before us indicates that such assistance could best be given by:—

(1) A grant of £2,000-0-0 a year for three years for an investigation of the biological control of insect pests of tea and other crops in Ceylon; and

(2) A grant of £1,000-0-0 towards the purchase of experimental, small-scale machinery and plant for the factory of the Tea Research Institute.

ROLAND V. NORRIS.

Director.

THE NEW BUILDINGS OF THE TEA RESEARCH INSTITUTE.

After considerable delay, due mainly to difficulties in acquiring a suitable estate, the permanent buildings for the Tea Research Institute are now under construction at St. Coombs.

LABORATORY.

The Laboratory, which is being built by the Colombo Commercial Co., Ltd. to designs and specifications prepared by Messrs. Adams and Small, Architects, Colombo, is a single-storey building consisting of two main wings for the chemical and biological departments respectively, connected by two small blocks containing accommodation for the offices and library and a photographic room. The general layout is shown in Fig. I from which it will be seen that the building occupies an area of approximately 180 ft. × 154 ft.

On the chemical side accommodation is provided for the Agricultural Chemist and Biochemist and their subordinate staff, together with a soil preparation room, a physical laboratory, machine room, distillation room, necessary store rooms and a spare laboratory to provide for future developments.

The biological wing will accommodate the Mycologist, Entomologist and Plant Physiologist and their staffs and also contains the necessary culture and sterilising rooms and stores. The layout is so arranged that this wing will face north, thus obtaining the most suitable light for microscopic work.

On the western side, connecting the two main blocks, is the Director's office and laboratory, accommodation for clerical staff and the library. The latter will be so arranged as to provide suitable accommodation for meetings and lectures. On the eastern side is a smaller block in which are situated the photographic room and dark room.

A portion of the inner quadrangle will probably be utilised for an insectory and pot culture house, but provision for these buildings is not included in the present programme.

All research rooms will be equipped with water, gas and electric light and power, the current required being obtained from the factory supply. The buildings, it is hoped, will therefore offer all facilities for the investigations of the major problems of the tea industry on up-to-date lines.

The cost of the buildings, including all bench fixtures, gas and water piping and sinks, drains, etc., but excluding apparatus and equipment, will be approximately Rs. 170,000.

STAFF QUARTERS.

Bungalow accommodation for the senior and junior scientific staff is being built by Messrs. Fonseka & Co., to designs and specifications prepared by Mr. S. Douglas Meadows, F.R.I.B.A. of Colombo.

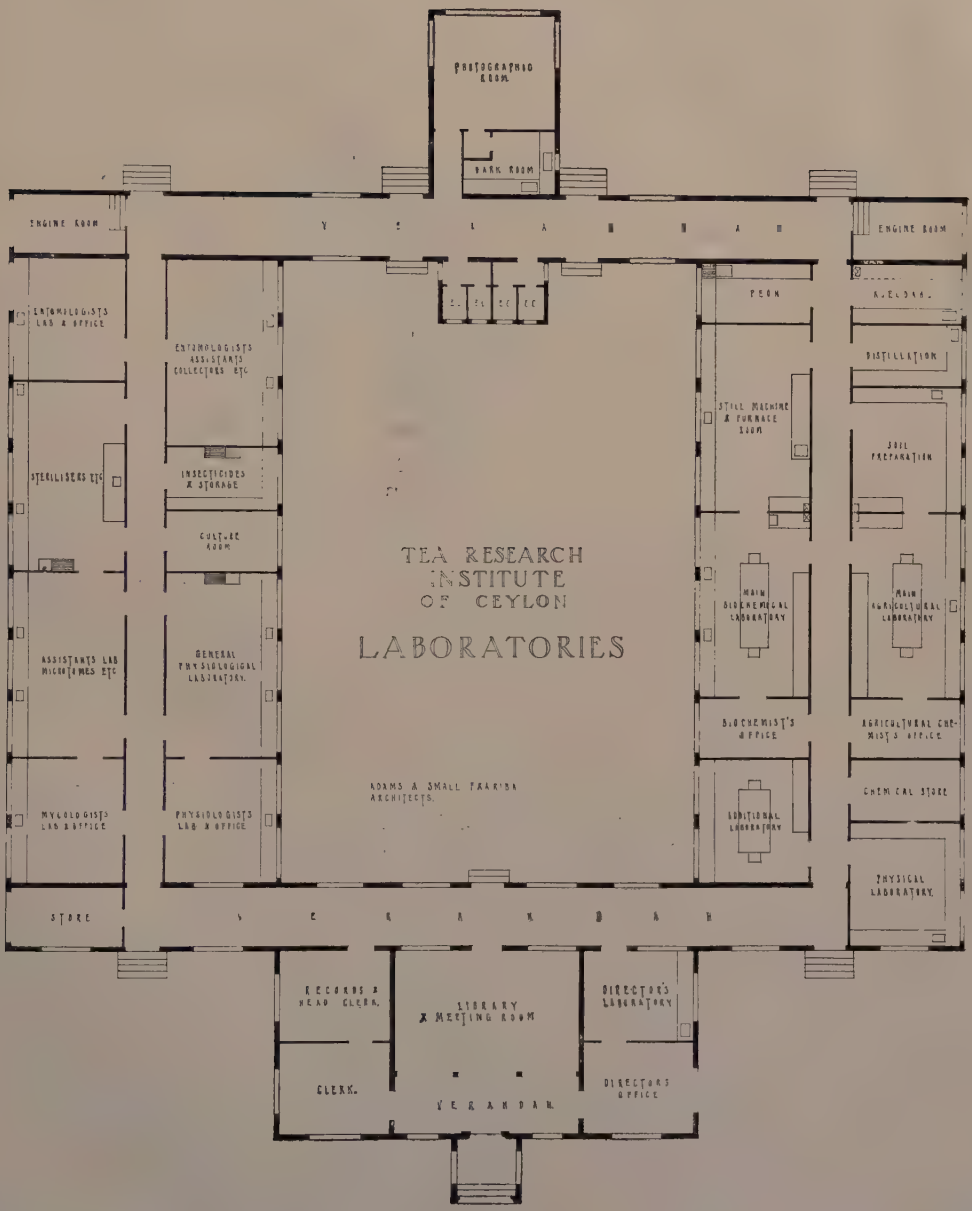
In the present building programme, provision has been made for six senior staff bungalows and five junior staff quarters, four senior and three junior types being constructed before the end of 1930.

Senior Staff Quarters.—Excellent sites for these quarters have been obtained on a high ridge giving accommodation for all six bungalows. The ground is such that, without taking up an undue amount of land, each bungalow commands an excellent view and is not overlooked by its neighbours, while good facilities exist for drainage. These bungalows will be of two storeys. Such an arrangement necessitates considerably less site cutting, leave more space available for gardens, etc., and permits of more satisfactory ventilation. The accommodation provided will be seen by reference to the plan shown in Fig. III. On the ground floor this consists of dining room, drawing room, lounge, one bedroom and bathroom, office, drying room and lavotory, together with kitchen, store and service rooms, two servants' quarters and garage. On the upper floor there are provided three bedrooms with two dressing rooms, two bathrooms, two lavatories and a linen room.

The houses will be built of stone quarried from the site, set in cement mortar and plastered over in cement mortar with a special rough cast on the outside walls. Upper floors are of concrete slab construction plastered in panels for the ceilings, the bedroom ceilings being of asbestos panelling. Each bungalow will be equipped with electric light, a water-borne system of sewage disposal connected to septic tanks, and the drying room will provide a hot-water supply. The contract price for each of these quarters is Rs. 41,330/-.

Junior Staff Quarters.—These are situated on high ground close to the entrance to the estate but within easy reach of the laboratory. These bungalows, the plan of which is shown in Fig. IV are of single storey construction and are being built of stone rubble set in cement mortar. The plan and arrangement of these bungalows have received the same careful consideration as the larger quarters, the accommodation consisting of a dining room, lounge, two bedrooms, bathroom, kitchen and store. Modern sanitation is being provided, together with adequate water supply and electric light. The contract price for each is Rs. 11,000.

Fig. 1


PHOTOGRAPHIC ROOM
DARK ROOM
ENGINE ROOM
ENGINE ROOM
VERANDAH
ENTOMOLOGISTS LAB & OFFICE
ENTOMOLOGISTS ASSISTANTS COLLECTORS ETC
STERILISERS ETC
INSECTICIDES & STORAGE
CULTURE ROOM
ASSISTANTS LAB MICROTOMES ETC
GENERAL PHYSIOLOGICAL LABORATORY
MYCOLOGISTS LAB & OFFICE
PHYSIOLOGISTS LAB & OFFICE
STORE
TEA RESEARCH INSTITUTE OF CEYLON
LABORATORIES
ADAMS & SMALL KANDY ARCHITECTS.
ROOM
STILL MACHINE & FURNACE ROOM
MAIN BIOCHEMICAL LABORATORY
BIOCHEMIST'S OFFICE
EDITORIAL LABORATORY
K. ELDAR.
DISTILLATION
SOIL PREPARATION
MAIN AGRICULTURAL LABORATORY
AGRICULTURAL CHEMIST'S OFFICE
CHEMICAL STORE
PHYSICAL LABORATORY
RECORDS & HEAD CLERK
LIBRARY & MEETING ROOM
DIRECTOR'S LABORATORY
CLERK.
VERANDAH
DIRECTORS OFFICE

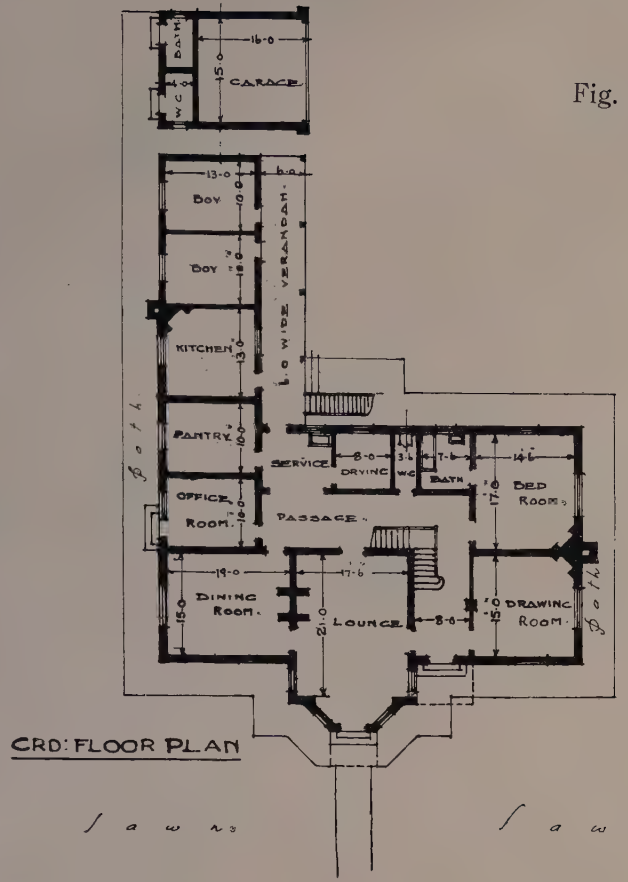
SENIOR STAFF BUNGALOWS ST: COOMBS ESTATE

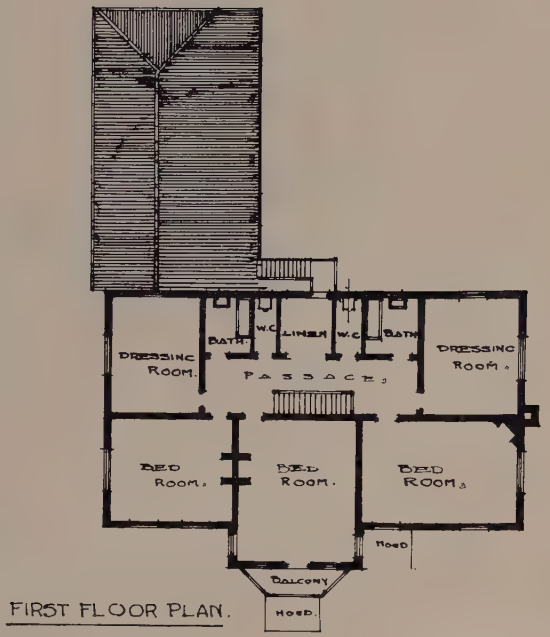
Fig. II

FRONT ELEVATION

SIDE ELEVATION

Fig. III


BATH
16-0
CARAGE
15-0
W.C
4-0
13-0
BOY
BOY
KITCHEN
10-0
PANTRY
OFFICE
ROOM.
10-0
10-0
10-0
10-0
6-0 WIDE VERANDAH.
SERVICE
8-0
DRYING
3-6
W.C
7-6
BATH
14-6
17-6
BED ROOM.
PASSAGE.
19-0
17-6
15-0
DINING ROOM.
21-0
LOUNGE
8-6
15-0
DRAWING ROOM.
Golf
Golf
CRD: FLOOR PLAN
lawn
lawn


DRESSING ROOM.
BATH
W.C
LINEN
W.C
BATH
DRESSING ROOM.
PASSAGE.
BED ROOM.
BED ROOM.
BED ROOM.
HOOD
BALCONY
HOOD.
FIRST FLOOR PLAN.

JUNIOR STAFF BUNGALOWS.

Fig. IV

FRONT ELEVATION

GROUND PLAN.

EXPERIMENTS WITH NITROGENOUS MANURES* (REVIEW).

General experience shows that the maintenance of an effective supply of nitrogen in tea cultivation is a necessary factor in the production of economic yields. In this respect tea behaves as do crops in general, and it is not overstating the case to say that the increased yields now obtained in agricultural enterprise all over the world are, to a marked extent, due to the application of nitrogen in manures to replenish the waning stocks in the soil. In no circumstances is the need more urgent than in those tropical countries where, with the combination of high temperature and high rainfall, the loss soon reaches alarming proportions.

For this reason experiments on the general use of nitrogenous manures, and on the most suitable form of nitrogen, must always form an important part of the experimental programme of institutes devoted to agricultural research. The two papers here reviewed are the results of such work at the two longest established Tea Research Stations. Consequently they represent a large part of the data which is available to tea growers.

The view-point of the two papers is fundamentally different, and it will be convenient to deal with each separately.

INDIA.

The Indian experiments form a series that has been running since 1920. They have previously been reported on in the Indian Journals of 1921 and 1924. The present paper gives the results up to the close of the 1927 season. The interpretation of the results is hampered by the change of policy which was made on two occasions. In 1921 no manure was given, and in 1924 a further addition was made to the "basal" dressing. The general scheme may be summarised as follows:—

Basal Manure to all plots.
- 1920-1923 — Bonemeal
- 1924-1927 — Bonemeal and Muriate of Potash.

Nitrogenous Manures 1920-1927 @ 30 lb. N per acre.
- Sulphate of Ammonia
- Nitrate of Soda.
- Green Manure.
- Oilcake
- Sinews and Skins.

Two points of interest stand out in the presentation of results: Firstly, the comparison between the efficacy of sulphate of ammonia and nitrate of soda, and secondly, the relative usefulness of such readily available sources of nitrogen compared with "organic

* (a) Experiments with different forms of Nitrogen at Borbhetta. Cooper, H. R., (*Quart. J. Ind. Tea Assoc.*, 1928, 179).
(b) Bemesting van Thee tuinen (Manuring of Tea Gardens). Garretson, A. J., (*Archief v.d. Thee cultuur*, 1928, 220).

manures." For the purposes of this review, attention is restricted to these two points.

The first conclusion in the Indian paper relates to the superiority of nitrate of soda in the first year, and in support of this contention the following table of results is given (page 180).

Percentage increase in yield due to manuring.

Nitrate of soda	...	10
Sulphate of ammonia	...	8·5
Green jungle	...	6
Oilcake	...	4
Sinews and skins	...	Nil

In considering these results it is necessary to relate how they were obtained. From March to May the whole number of plots, eighteen in all, were cropped as a uniformity trial. During the following months till November the manures were in action on all but three reserved as check plots. At the close of the season the yields on the check plots for the two afore-mentioned periods were compared, with the result that the second period gave 4·12 times as much crop as the first. This factor was then employed to calculate the probable yield of the other plots, *supposing that they had been left unmanured.* This is a straightforward calculation based upon the known yields of all plots prior to manuring. Hence, from the actual yields derived from the manured plots and the calculated normal yields, a percentage increase figure is obtained. Everything, therefore, depends upon the degree of reliance that can be placed on the calculated figures for normal yields. The differences between the actions of the various manures seem so slight that an examination of the underlying presumption is desirable.

The following data are taken from the uniformity trial conducted by the Tea Research Institute on a selected piece of experimental land in Nuwara Eliya. The size of the Indian plots is 54 bushes. The nearest unit of size at Nuwara Eliya for which data are available is 42 bushes. The design of the Indian experiment was accordingly superimposed upon the requisite number of plots of the uniformity trial and the yields of these plots calculated over two consecutive periods corresponding to those of the original experiment. The yield ratios 2nd period/1st period for the means of the triplicate plots assigned to each hypothetical treatment are as follows:—

Check	...	1·543	
Nitrate of soda	...	1·473	Standard deviation = ± ·05085
Sulphate of ammonia	...	1·489	
Oilcake	...	1·451	= 3·356%
Green manures	...	1·557	
Sinews, etc.	...	1·577	
Mean	...	1·515	

It will be seen that the ratios are by no means stable, and that the magnitude of the deviation would render invalid the fine distinctions involved in the former table unless evidence could be brought

to prove that a similar degree of dispersion to that shown here was inapplicable under the conditions of the original experiment. The writer has previously held (*Tea Quarterly*, 1928, I, 63) that the percentage increase method, by introducing unknown errors, must be rendered suspect, and this view is confirmed by the data now in process of accumulation.

The apparent residual effect of nitrate of soda, shown on page 185, seems also to be overstressed.

Yield as percentage of yield of check plot.

	1920	1921
Nitrate of soda	106·5	104·0
Sulphate of ammonia	100·0	94·0
Oilcake	98·0	99·0
Green manure	107·0	116·0
Sinews	99·0	100·0

The argument runs as follows:—

> "The nitrate of soda plots in 1921 were about 4 per cent better than the check plots. In 1920 before manures were applied the yields from March to May indicate that they were then about 2 per cent worse. The sulphate of ammonia plots were about 6 per cent worse than the check plots in 1921, and also in early 1920 before manures were applied. It appears then that, while sulphate of ammonia exercises no residual effect in the year following that of application, there is some residual effect from nitrate of soda."

We have already dealt with the question of stability of percentage increase which enters into this argument also, but another consideration remains. Any difference between means of a number of similarly treated plots is only significant if it exceeds by the requisite amount the variation of the individual plots. An examination of these individual members of the triplicate shows however that this is not the case. The variation of similarly treated plots is so great that statistically, not only is there no reliable difference between the falling off of nitrate of soda and sulphate of ammonia treatments, but, with the possible exception of green manure in 1921, there is no difference in the relative yields of any of the treatments.

With experiments conducted only for a year this lack of definition frequently occurs, and a truer perspective will be gained by turning to the years 1924-7 when treatment was constant over a long period. The Indian conclusions, based somewhat arbitrarily on the last three years, favour the supremacy of sulphate of ammonia with reservations (not based on the experiments) in favour of its joint use with organic matter.

The figures which follow relate to the mean yields of the triplicate plots for each treatment over the last four years. They are expressed in decimals of pounds for convenience of calculation.

	Mean Yields.	Excess over check.
Nitrate of soda	234·36	**57·33**
Sulphate of ammonia	240·80	**63·77**
Oilcake	226·30	**49·27**
Green manure	247·73	**70·70**
Sinews, etc.	214·30	37·27
Check	177·03	—

Standard error of difference between means = 18·44 lb.
= 8·25%

Significant difference between means = 42·04
= 18·8 %

It remains to determine the errors associated with these mean yields. Examination of the original data showed that the variation in yield, apart from that due to treatment, was almost entirely due to errors of parallel plots, and that the discrepancy in triplicates was only to a very small degree due to systematic differences between the sets of replications.

The mean yield is 223·42 lb. with a standard error of difference of 18·44 lb. or 8·25%. The value which must be exceeded in differences between treatments, as determined from the "*t*" function, is accordingly 42 lb. Only if the differences between treatments exceed this latter value can they be relied upon to be due to the effects of treatment. Any smaller differences are attributable to errors in the conduct of the experiment. For the differences between nitrogen treated plots and the check plots, those which are significant are printed in heavy type.

It is therefore seen that

(1) All the nitrogen plots except sinews show significant increases in yield over the control;

(2) The data are not reliable enough to distinguish any order of priority in effectiveness of the other four treatments.

In these circumstances there is no point in looking for soil acidity differences to explain the fortuitous advantage due to sulphate of ammonia as reflected in the untested yield figure.

The foregoing criticism of the Indian work has its positive aspects. The foremost of these is the necessity of testing data for consistency on the lines of this review before drawing conclusions, and secondly the need for making efforts to reduce experimental error to a magnitude in keeping with the differences expected between treatments. A margin of error which does not discriminate between differences of nearly 19 per cent is altogether too coarse for differentiating between the qualitative aspects of nitrogenous manuring.

Tht key to the situation lies in increasing plot size. The writer has shown (*Tea Quarterly*, 1929, II, 66) that experimental error can be steadily diminished up to a plot size which is approximately seven times that employed in India (54 bushes). Alternatively, a much greater replication must be used.

JAVA.

The Java experiments are large-scale demonstrations carried out as co-operative experiments on estates. There is accordingly some difference in relative size and design. As a rule each treatment was at least in duplicate, and the size varied from one half to twelve acres per plot. Realising the problem of soil and bush heterogeneity, various methods were adopted to counteract inequality. The chief of these was to ascertain the productivity for a period before the actual experiment began. Where plots were markedly uneven in yield the manured and unmanured were divided among the high and low yielding plots. Where even this limited replication was not possible, the highest yielder was always chosen as control.

It is interesting to contrast the technique of these large-scale experiments with those previously described. The Java experiments make the original yields the basis of all comparisons. Somewhat of the same objection may be raised with respect to comparable yields as in the Indian work.

We have shown that the innate variability in yield behaviour of a plot may lead to different degrees of response at different times. There is therefore the possibility that in the preliminary round two plots with markedly different yields may converge at a later date, or *vice versa*.

By consciously taking the lower yielder as the subject for manuring, this contingency is largely guarded against as far as interpretation is concerned. At any rate, in this case, a smaller risk of error is encountered than by forecasting the behaviour of the plots, not from the previous record of the same plots, but from the previous record of quite different ones. Other commendable precautions were also taken, such as employing the same pluckers for both treatments and control, and, where absolutely simultaneous pruning was impossible, giving the benefit in production to the unmanured plot.

The results do not stand on the merits of single trials. In a number of cases, strips, large blocks, and more refined plot experiments were running on the same estate in close proximity. It is possible that by combining these varied efforts into one more detailed trial, the experimental value would have been enhanced, but they have undoubtedly had a valuable demonstration value on the estates in question which will encourage superintendents to work on these lines themselves.

Since the manuring described in the paper is in terms of grams per plant, and the number of bushes per acre is not stated, it is impossible to convert these doses into pounds per acre with any

accuracy. On the basis of a 3 ft. 6 in. × 4 ft. spacing each 10 gms. of manure per plant accounts for approximately 70 lb. per acre. The manuring is therefore more liberal with respect to nitrogen than in Ceylon, since quantities up to 60 gms. per plant (420 lb. approximately per acre) are used in addition to green manures.

A selection of results is given below:—

Summary of Java Results.

Comparison.	Duration of Experiment in months.	Grams manure per bush.	Increased yield due to manure. Lb. dry tea per acre.
(1) Sulphate of Ammonia v. Unmanured.	13	35	180
(2) Do	15	35	169
(3) Do	19	35	190
(4) Do	17	50	187
(5) Do	26	(2 applications of 240 lb. per acre at 4-month intervals).	636
(6) Urea v. Unmanured	18	25	124
(7) Do	16	25	340
(8) Urea v. Oilcake	17	(2 applications urea 10 gms. at 4-month intervals) 100 gms. oilcake on control.)	154
(9) Urea and Bonemeal v. Bonemeal	15	10+10 U and 40 B.M. 40 B.M.	225
(10) Sulphate of ammonia v. S/Am.+Bonemeal v. Unmanured	18	40+20 4-month interval. 40+50 B.M.	S/Am. v. Unman, 453 S/Am. & B.M. v. S/Am. 161 S/Am. & B.M. v. Unman. 526
(11) Whale Guano	17	(a) 50 (b) 100	(a) Single 478 (b) Double 607

According to length of time and initial fertility the same manure gives different results. Nitrogen appears to have been uniformly successful either with or without phosphate, whilst phosphate is beneficial in the one case where this is tried with a nitrogenous manure.

The results from both these centres demonstrate therefore the benefit of nitrogenous manures, but the question of relative efficiency must await more detailed results.

T. EDEN.

A FEW OBSERVATIONS ON MODERN TEA FACTORIES (REVIEW).

When the cost of production is increasing and outside competition is keen, the well-being of an industry depends to a great extent on the rational application of modern technical improvements and the judicious introduction of mechanical devices which make for economy of labour and result in the out-turn of a more uniform product. The tea industry has been aware of the benefits accruing from improvements in cultivation and manuring, while during recent years attention has been given to factory improvements. Dr. Deuss of the Tea Experiment Station, Java, has published some pertinent remarks on, and suggestion for, the improvement of the process of tea making in *De Bergcultures* No. 39, and in the *Archiefs voor de Thee Cultures* No. 2-3. April-June, 1929. Although it is not expected that all these suggestions will be accepted by the industry, it is intended that they should draw attention to possible lines along which improvement may be effected, and pave the way to a greater degree of mechanisation of the industry. As the author points out, some of these proposals may fit into the scheme of working in one factory, while other proposals would fit in better in another factory.

Dr. Deuss introduces the subject by stating that the quality of the tea must be maintained at all costs. He does not regard high grown teas as being the only quality teas, but considers that these are prized on account of their special characteristics, and that good quality tea can be made at any elevation. There is no truth in the statement that judicious manuring destroys quality; although manuring may affect the quality of the tea, this has never been observed with well-planned experiments.

The ill-effect attributed to manuring is generally due to lack of factory accommodation to meet the increased crop obtained as a result of judicious manuring. If an estate, which produces 500 kilos of dry tea per h.a. and has a factory capable of dealing with this crop, increases its crop to 700 kilos dry tea per h.a., then there will not be enough room in the factory to deal with the increased crop in a proper manner. Withering will be a difficulty and the quality of the product will suffer unless the factory accommodation is increased. Many factories are also short of space for withering during the rush months, and reserve tats are advised to be kept. These are filled with fresh leaf in the main corridors of the withering lofts when this is necessary, and they are then pushed into the transverse passages for withering. In this way the whole of the superficial area of the lofts is used, and the spreading capacity of the factory greatly increased.

If a good quality tea is wanted, it is essential to have a well-planned factory working in an economic manner. The latter condition can only be fully attained when mechanical aids have been appreciated and introduced. Mechanisation of the transport of the leaf from the field to the factory is carried out by replacing the carrying coolies by ropeways and motor trucks, and this leaves the pluckers in the field to carry on with the harvesting, so that more leaf per plucker is obtained. Again the leaf comes into the factory as a continuous supply in a fresh condition and there is less risk of damaged leaf, all of which makes for good quality tea. It is claimed that chests and especially baskets are the best for carrying leaf by ropeway, but these must not be packed too tight, or the leaf stamped down in any way, otherwise the leaf is bruised and discoloured on the way to the factory. Where the leaf is carried long distances by motor, the body of the truck is divided into compartments by wire gauze. The baskets will then rest on shelves of gauze and not press on each other, and a warning is given against allowing coolies to ride on top of the load.

Unless the leaf comes by road or cable to the level of the withering loft it is necessary to carry the leaf up to the various chambers and for that purpose, lifts, transport bands with blocks of wood on which the loads rest, or plain transport bands are advocated. If a simple transport band is used for fresh leaf, then it must be concave and not flat, otherwise the leaf can only be spread in the middle of the band owing to the risk of spill. As the fresh leaf is emptied on to the band it means more handling of the leaf, which is to be deprecated, so that this system is not looked upon with favour.

When a transporter is used the baskets are placed directly in it and travel up to the loft along the length of the factory. In the loft the baskets pass along a sloping plank on to another transport band placed below the first and travelling across the loft to the opposite corridor where they slide on to another band travelling the length of the factory. The baskets are then taken off at various points for spreading. Very little power is required for the transporter, and it is not necessary to attend to the baskets during transport. One disadvantage is that it takes up a certain amount of space and the wear-and-tear is rather heavy at the crossings.

It is suggested that monorail tracks can be utilised in tea factories to a great extent, and plans and sketches of the Tourtellier system are given in the article under consideration. This system consists of a series of tracks along which the load or basket travels suspended from two small wheels which run astride the track. The wheels cannot fall off and considerable weights can be moved with ease. The tracks or rails need not travel in straight lines but can be made to branch by automatic switch points so as to reach any desired spot.

Although this elaborate system is not yet working in any factory, Dr. Deuss is of the opinion that it could be usefully adapted, and mentions two estates, Sedep and Sinambra, where a simple modification of the monorail is being tried out. The monorail requires little upkeep and may be worked by hand or electrically. It is a simple matter for one cooly to move 200 pounds in this way, whereas at present 100 pounds is a sufficient load for two men.

It is pointed out that throwing the withered leaf from the tats on to the floor before it is taken to the rollers is not good for the leaf, and it is suggested that the leaf could fall into a smooth channel from which it is swept on to a transport band running in the passage just below the channel. This band carries the leaf to the roller shoot holes. If open top rollers are used for the first roll, the leaf can fall into the roller from the shoot in the floor of the withering loft. There should, therefore, be no spill, and filling can be carried out from the loft without attention below.

Rolling involves many men for emptying the rollers, carrying the rolled leaf to the roll breakers, and then taking the bulk to the rollers to be rolled again, and also carrying the rolled leaf to the fermenting chamber. If there are not enough men for this, the tea is allowed to lie about and becomes dull. A novel suggestion is tentatively put forward to overcome this difficulty while economising in the number of men employed. The author makes no claim of the practicability of the scheme as it stands, but evidently feels that some improvement can be effected here. His idea is to put the rollers in sequence on a series of stepped platforms, so that the open top rollers which take the withered leaf for the first roll are on the top step. When the first roll is completed the leaf falls from the roller on to the hopper of the roll breaker which stands beneath the roller. The leaf is than sifted, the fine leaf falling into containers which go by monorail track to the fermenting chamber, while the bulk falls into the next roller, which occupies the next platform below. The rollers should be fitted with automatic pressure regulators so that they will not require any attention. The rolled leaf thus travels from one roller to the other step by step, the big bulk being eventually taken by monorail to the fermenting chamber. It may be possible to carry the rolled leaf into the fermenting room by means of a band which travels through that room, but the monorail is considered simpler in execution. The rolled leaf is fermented in the containers and, when ready, the container is again connected to the monorail and carried up to the level of the drier feeder where it empties automatically on to the feeder, thus doing away with the man generally used for feeding the drier. This system of carrying the leaf from the fermenting room to the drier is in use at Rantja Bolang, and it seems to be capable of improvement.

The system of stepping the rollers involve more roll breakers, but this is not considered to be a disadvantage because of the saving in the number of men required. A battery of rollers, under this scheme, can be worked by one man, so that only six would be required for a three-roll programme in a factory turning out 1,250,000 kilos (about 2,500,000 lb.) of dry tea per year. The transport of the rolled tea from the roll breakers via the fermenting room to the drier will only need six more men. If the stepping system, which means a very large rolling room, is not adopted, there is no reason why Jacob ladders or transport bands should not be used to carry the leaf from one roller to the other. Although the stepping system appears more intricate, it is, however, the simplest. To facilitate cleaning of the rollers and roll breakers, small electric hand brushes should be introduced.

Transport bands can also be used to carry the dried tea from the drier to the sorting room. The tea falls from the drier on to the band, and is carried away so that there is no accumulation of tea by the driers. Incidentally, the band transport supplies a good way of cooling the tea before it is heaped, and stalk can be picked out as the band moves. This arrangement may be replaced by a pneumatic device which seems to be well adapted for this purpose as the tea is not damaged. It is claimed that a distance of 10 metres can be easily bridged by the suction of an ordinary fan. In this way the tube connected to the vacuum would dip into the tea by the drier and suck the tea over into the sorting room, then from the sorting room into the bins, from there to be automatically bulked, and finally into the chests on the packing machine.

It is pointed out that the adoption of mechanical devices would effect a great saving in the number of factory hands required, but it appears to me that such a complete mechanisation would involve the loss of a certain amount of control. Success in tea making is only obtained by attention to detail and a close supervision of each process, correcting faults as they occur and varying the process to tally with the variation in the quality of the leaf, the degree of wither, and the climatic conditions existing at the time. However, as pointed out by Dr. Deuss, there is a wide field to be explored in the direction of mechanising and co-ordinating the various processes in the factory, and I have no doubt that big advances will be made when the manufacturers of tea machinery realise the need of this and give it their serious consideration. The sugar and flour industries have been highly successful in applying mechanical means to the processes in their factories, and, although there are several factors which militate against the tea industry attaining the same success, there is no reason why a greater degree of mechanisation should not be introduced in the future.

D. I. EVANS.

STALK EXTRACTING MACHINE—LOTH PATENT (REVIEW).

In "*De Bergcultures*," No. 54, 13th July, 1929, Herr A. R. Sloos of Tjiboengoer submits a short note on a Stalk Extractor which has been in use on his estate since the beginning of May. The first small experimental machine was set up by Herr Loth on the Sockamadjoe Estate, and the experiments with various tea grades were carried out under the guidance of the Tea Experiment Station.

The machine is a shaker, consisting of a perforated copper plate through which the tea falls. It had been said that it was necessary to determine the correct perforation required for each grade of tea of any particular grade, but the machine used on Tjiboengoer specially for pekoe was also used for pekoe souchong and orange pekoe.

The machine works quickly, but the tea must glide along and not jump along the perforated plate, so that the curled black tea is held in the holes, works its way into the plate and falls out below. The greater portion of the smooth stalks glide down over the plate and are caught separately. The perforations must be arranged in such a way that the tea can fall through the plate, and the speed must not be too great or else too much tea will pass along with the stalk.

Herr Sloos, whilst saying that he found the machine satisfactory, does not claim perfection, but points out that it can be of great use for the sorting. All the stalks cannot be separated, and tea so treated must be picked over again by hand. The work of picking over, however, can be done two to four times quicker when the tea has been thus treated.

Sometimes the stalks are too long, and Herr Loth has provided for that by fitting a tea breaker to the van Assendelft de Coningh sorter instead of a tea-cutting machine. The breaker, which crushes the stalks but not the smaller bits, can be fitted to a Davidson sorter also.

The machine is to be exhibited and demonstrations given by the firm Rottke and Otto at the Agricultural Exhibition. This firm has constructed a slow-working feeder which can be controlled by means of a small hand wheel, so that the quantity of leaf which falls on the copper plate can be regulated.

The capacity of the pekoe machine is about 100 lb. per hour of once treated tea, and it costs 1,750 florins, exclusive of motor and erection.

D. I. EVANS.

QUARTERLY REPORT ON THE WORK OF THE SCIENTIFIC STAFF, TEA RESEARCH INSTITUTE.

The following review relates to the quarter ending 30th September, 1929:—

The scientific work of the Institute has been restricted during the period under review owing to the diminution of staff due to the absence of Dr. Gadd on leave and the resignation of Mr. Stuart Light. Moreover, until the arrival of Dr. Norris, the new Director, on August 12th, the time of the Agricultural Chemist was largely occupied with administrative duties. By kind permission of the Director of Agriculture, the advisory work in Mycology and Entomology has been carried out by Mr. M. Park and Mr. F. P. Jepson, respectively.

Fifty-three specimens for mycological examination were sent to Mr. Park who reports that *Poria* was the disease most commonly found. Several examples of Wood Rot (branch canker) were also received and it seems likely that any continued neglect of this trouble will lead to a steady degeneration of old tea at mid and low-country elevations. Some loss has also been caused by Red Rust, while Diplodia is still common at lower elevations. Specimens of the common leaf diseases have also been received, but there is no evidence that these have been of a serious nature. It is satisfactory to note that there is no record of any new disease nor do any of the known diseases appear to have been unusually common.

Thirty-seven specimens for entomological examination have been received. Mr. Jepson reports that the majority of enquiries related to mites which have been much in evidence, following the unusually dry weather. Several cases of insect damage to green manure plants have also been reported. Dadaps in the Dolosbage District were damaged by the snail (*Amphidromus Ceylanicus*) this being the first record of such injury.

Work on *Trichogramma* breeding has been continued by the entomological assistant under the guidance of the Director. As mentioned in the last Progress Report, the percentage parasitisation obtained with *Sitotroga* eggs, though at first fairly satisfactory, steadily fell off with the result that the numbers of parasites obtained rapidly declined. The use of *Sitoroga* egg has consequently been abandoned, and the ova of another moth, *Corcyra cephalonica*, have been employed instead. This material has yielded much more promising results. Experiments have also been carried out to ascertain the number of eggs which the parasite can infect, with the result that it has been found perfectly feasible to work with a proportion of twenty or even twenty-five eggs per parasite instead of six, the

number employed in the earlier experiments. This procedure naturally allows of a much more rapid increase in parasite numbers, and in fact, the rate of increase now is six or seven times that formerly obtained. The chief problem at the moment is to increase as rapidly as possible the number of moths and thus maintain a large supply of the eggs. Data are being accumulated on these points, which will, it is hoped, enable the new Entomologist to take up the matter on a larger scale.

The Agricultural Chemist has been chiefly engaged in the separation and analysis of the clay fraction of typical tea soils and, in view of the importance of this fraction, this work will be continued as a routine operation. The results so far obtained point to an incomplete laterisation of up-country soils, the silica-aluminium ratio obtained being definitely higher than those found in true laterite. The higher ratios may be due to presence of uncombined silica in the clay fraction, produced by the weathering of the large silicious content of soils derived from gneissic rock.

A considerable number of enquiries regarding the making of artificial farmyard manure by the Adco process have been received. In most of the samples of such material which have been sent in, the nitrogen content has been considerably lower than might be expected in properly prepared manure. Mr. Eden has consequently begun an investigation of the process of manufacture, and an experimental pit has been constructed in order that the cause of the nitrogen losses may be determined, and to distinguish between losses occurring during manufacture and those due to storage. As many members of the planting community have probably made trials of the Adco process, details of their experiments would be welcomed.

The uniformity trial at Nuwara Eliya has been continued and an examination of the data for twelve months completed. It is of interest to note that as the tea nears the completion of its pruning cycle the errors in plot comparisons grow larger. It is however satisfactory to find that the average error for twelve months' plucking is slightly lower than that for the six months previously reported.

The Biochemist has continued his analyses of leaf samples from the field plots and of samples both of leaf and made tea sent in by estates. The data thus obtained supply a good deal of information concerning the variations in the composition of both fresh leaf and made tea. In the fresh leaf the water soluble content is inversely related to the rainfall, and the same relation applies to the made tea. Climatic effect, therefore, persists in spite of any change produced during manufacture and has a marked effect on the quality of the tea made.

About 40 to 50 per cent. of the water soluble material consists of tannin bodies. Both the tannin and the water soluble material decrease when the monsoon starts but, whereas the total soluble extract diminishes steadily throughout the wet season, the tannin reaches a limit beyond which it does not fall. The tannin content then fluctuates about this level and in some cases may rise. When this happens the valuation of the tea increases. There thus appear to be two distinct types of tea. One is a high quality tea possessing strength, body and pungency, made during the dry weather, when the extract and tannin content are alike high. The other is a good quality, pungent tea, obtained during the wet weather, which will have a low extract and tannin content, but in which the proportion of tannin to other substances is high. Generally speaking the tannin content, however, especially that of acid soluble tannin, follows the market valuation very closely, and is therefore one of the main factors governing quality.

Dr. Evans has also continued his study of the changes taking place during manufacture. His results agree with those of other workers in showing a steady decrease in the water soluble material of the leaf during manufacture. This loss is rapid in the early stages of fermentation, but is almost negligible when the tea is considered ready for firing. The total tannin decreases in the same way but at the same time a tannin derivative is produced which is precipitated by dilute acid. The amount of this substance increases during fermentation and forms from 19 to 30 per cent. of the total tannin when fermentation is complete. The determination of the water soluble extract appears to be a good criterion of the rate at which these changes take place. An extract of tea contains a good deal of colloidal matter and the tannin seems to act as a hydrophylic colloid which becomes more easily precipitable as fermentation proceeds. As these properties have a marked influence on the quality of the liquors obtained, an examination of the colloidal constituents of the extract is being made in the hope that this may throw some light on the changes undergone by the tannin bodies during fermentation.

ROLAND V. NORRIS.

Director.

NOTICES.

Appointments.—Mr. C. B. R. King, M.A., has been appointed Entomologist to the Tea Research Institute. Mr. King, who has been working under the Empire Cotton Growers' Corporation in Nyasaland and Mozambique, is at present studying the methods of parasite breeding in use at Farnham Royal Laboratory, and is expected to arrive in Ceylon early in December.

Mr. F. R. Tubbs, B.Sc., has been appointed Plant Physiologist to the Institute. Mr. Tubbs is at present undergoing further specialised training at the East Malling and Long Ashton Research Stations, and will probably arrive in Ceylon next February.

Advisory Work.—Up to February 10th mycological specimens on which reports are required, should be sent direct to Mr. M. Park, Department of Agriculture, Peradeniya.

Entomological specimens should similarly, *up to December 15th*, be sent to Mr F. P. Jepson, Department of Agriculture, Peradeniya. After December 15th such specimens may be sent to the Tea Research Institute, Nuwara Eliya.

Visitors' Day.—Manufacture has now begun in the new factory at St. Coombs Estate. The first Wednesday in each month has been set aside as a visitors' day, when it is hoped anyone interested will visit St. Coombs. Visitors at other times will, however, always be welcome, but it may not be possible to offer the same faciliites as on visitors' day.

St. Coombs Estate is reached by taking the Mattakelle turn-off from the main Nanu Oya-Talawakelle Road, a few miles above Talawakelle. A sign-post has been erected at the turn-off.

ROLAND V. NORRIS.
Director.

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Edited by

ROLAND V. NORRIS, D.Sc., F.I.C.

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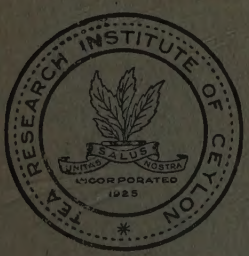

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